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# A RE-EXAMINATION OF THE COCONUT CADANG-CADANG QUESTION [1/]

J. R. VELASCO

WITH EIGHT TEXT FIGURES

Much has been written on the cadang-cadang of coconut, but for the most part, it is speculation on meager knowledge. Theories on the nature and cause of the disease have been proposed implicating in their turn a virus, some other pathogenic organism, the soil, typhoon, nematode, mealy bugs, sulfuric elements and radioactive dust from volcanoes, etc. The difficulty is that most theories are propounded, not so much as to be a working hypothesis in probing into the mystery, but rather with an attitude of finality. It is assumed that the burden of disproof rests with the doubting mind.

There were, however, some serious attempts to contribute to our knowledge of the cadang-cadang problem (Ocfemia, 1937; Reinking, 1950; Kent, 1953; de Leon and Bigornia, 1953; Price, 1957; and Maramorosch, 1960). It is only regrettable that the discussions are heavily slanted towards the virus theory, and as a result there is at present an overwhelming consensus that the disease is in fact caused by a virus.

The present discussion is an attempt to review certain aspects of the foundation upon which the virus theory rests and to explore the alternative views.

## SPREAD AND MOUNTING DAMAGE

The literature is replete with claims that the disease is spreading and the damage from it is mounting. For instance, the preface to the *Abstracts of Philippine Publications on the Cadang-cadang Disease* (Anonymous, 1960), stated thus, "A certain virus disease of the coconut palm, called cadang-cadang in Bicol dialect, has be-

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1/ General contribution No. 912. The experiment conducted by the writer and his colleagues were supported in part by the Cadang-Cadang Research Foundation Grant to the U.P. College of Agriculture.

come a severe menace to the agricultural production of the Philippines. The first case of cadang-cadang was observed in 1914 in Nabua (Camarines Sur). Slowly it spread over the whole Bicol region, i.e. Southern Luzon, and is now advancing to the west (Bondoc Peninsula), to the east (Catanduanes) and to the south (Masbate and Samar). More than 8 million trees are already affected by it."

Reinking (1950) reported that "one clear-cut example, among others, of destruction due mainly to the cadang-cadang disease is presented in San Miguel Estate in Albay Province. Land for this estate was cleared in 1920 and the main part planted in 1924. Of the 260,000 bearing trees at the peak of planting, 116,000 were standing in 1950 . . . Production in 1947 was 260 tons of copra in a 12-month period; in 1949-50 it was 55 tons." Reinking continued: ". . . The observations reported here would indicate that the disease is infectious . . . Further study is needed, but these preliminary investigations tend to substantiate Celino's virus findings."

The observations on San Miguel strongly support the contention that the damage due to the disease is mounting. They are not enough to sustain the claim that it is spreading in the sense that a pathogenic disease spreads. To prove the pathogenic nature of a disease, one has to show among others that it can be transmitted.

Mounting damage can equally be an indication of a widespread occurrence of a causative agent like a soil factor or a climatic factor. One example of this alternative is the flowering or tasselling in a sugar cane field in December. One day we may discover that one cane in a field has tasselled. (Let us assume that tasselling is just as undesirable as a diseased condition because it lowers the sugar content of the canes.) The next day, two or more canes tassel and as the days pass by more canes follow suit until the whole field comes to bloom. Obviously, we could not conceivably conclude that the tasselling impulse has been communicated from one cane to another.

By the same token, the pattern of *spread* of death in a coconut plantation could have reflected the response of plants to a common non-infecting cause. The coconuts in San Miguel could have reached the critical age for dying at 20 years of age. This does not mean

that all of them would die at 20. They would form a frequency-distribution pattern of death clustering around 20 years of age. Depending upon their individual capacity to withstand the factor which causes quick decline, some may die younger than 20 years and others may reach a ripe old age. It is conceivable that these trees would fall under the same frequency distribution because the coconut is normally a cross-pollinated species and is therefore highly heterozygous. In comparison, rice, a self-pollinated species, can be delayed or advanced in its flowering by judicious applications of fertilizers so that the span of flowering is one month. If the life cycle of rice is 130 days, the span of flowering will represent 23 per cent of its life cycle. Assuming that the same variability obtains in coconut and that the normal life span of coconut is 70 years, we can see that a difference of 16 years between two neighboring trees in their response to a common factor would still put the trees in the same population (frequency distribution).

One question that may be raised is, if it is not a virus why did cadang-cadang spread from the northwest part of San Miguel Island to the southeast part (Price, 1957) until all areas of the island were affected? This may be answered by asking another question: When the island was planted to coconuts in 1920 to 1924, did the planting progress from the northwest part to the southeast part?

Another question which has been asked is, why does it spread to Bondoc Peninsula and the other parts of Quezon Province? The writer's observation is that with the possible exception of some places in Guinayangan, Quezon, the reported cases of cadang-cadang in Quezon are very different from those of the Bicol areas, not only in appearance but also in the pattern of incidence. The following discrepancies are worth considering: (1) While in the Bicol Peninsula the leafscars on the trunk at the height of one to two meters are far apart, those in Quezon are closer and evenly spaced. (2) Severe cases in Quezon, unlike those of Bicol, do not exhibit the the dark-green, short, closely packed, tufted leaves. (3) In many places in the Bicol region, young trees which are considered still healthy already possess sparse crowns. (4) The incidence in Quezon does not occur in extensive areas and neither are there signs that it would be extensive. The unhealthy trees are localized in places of poor drainage or in areas of thin top soil, underlain with impervious tuff. In other words, while the unhealthy trees are

an exception in Quezon, they are the rule in Bicol.

It may be recalled that unhealthy trees have existed right along in Quezon, Laguna, and in all the provinces of the Visayas and Mindanao. It is likely that they will eventually, if not presently, be classified as cadang-cadang when they become convenient argument for the *spread* of the purported virus.

To recapitulate, the virus theory of cadang-cadang rests mainly on the observation that once cadang-cadang strikes a plantation, damage from the disease progressively mounts, and that reports of incidence in places farther and farther away from the initial site of "infection" are being made from time to time. These observations were adduced to mean that the disease is spreading. Attempts have been made to supplement this line with evidence along two other lines: (1) studies of transmission of the disease from one coconut to another and to other plant species, and (2) studies on soils and fertilizers.

1. Transmission of the disease is considered by most workers as essential in proving the pathogenic nature of the disease. Cognizant of this, Celino made early attempts to transmit cadang-cadang. In 1947, he came out with the claim that he succeeded in his attempt with the use of needle pricks. On inoculated 3 to 4 year-old plants, he observed "pale white to brown areas on the pinnae of newly opened leaves consisting of dots to short narrow dashes, 2 to 3 mm. wide and 5 to 10 mm. long." However, in an earlier report, Celino (1947a) said that in the field, "the disease usually starts in the form of small and distinct water-soaked lessions."

Although the results obtained by Celino were not widely accepted, they spurred further effort at transmitting the disease. More intensive studies were made possible with the coming of dollar aid and the assignment of specialists to the Guinobatan Experiment Station beginning in 1950. Experiments were done in earnest so that after three years, de Leon and Bigornia (1953) were able to report that "transmission of kadang-kadang symptoms to healthy trees appears to have been secured through two separate means: (1) insects and (2) pollen." Unfortunately these claims have not been subsequently confirmed by other workers. Price (1957), reporting on the follow-up experiments of Bigornia, Calica and Pableo, concluded that "since there was no significant difference in incidence of yellow mottle decline in inoculated, as contrasted with non-inoculated trees, none of the species of insects

tested can be implicated as a vector of this disease."

Meanwhile, Celino and his group, operating independently of the Guinobatan group, continued their transmission experiment and in 1953 (Celino, Javier and Miranda, 1953) evaluated their results as follows: "1) cadang-cadang is caused by virus, 2) transmissibility of cadang-cadang by mechanical means as found in earlier experiments has been confirmed, 3) cadang-cadang of coconut virus can be transmitted mechanically to *Phaseolus vulgaris* and *Phaseolus calcaratus*, on which the mosaic mottling symptoms are exhibited, and 4) the incubation period in the young coconut seedlings are longer than that required by *Phaseolus vulgaris* and *Phaseolus calcaratus*, confirming the rigidity of the coconut tissues".

This was followed by the announcement in 1954 that Miss Santos, one of Celino's colleagues, obtained from the extract of *Phaseolus* some infective crystals that are brownish, readily soluble in water and rod shaped or nearly so as seen under a high power microscope (Anonymous, 1960, p. 11). The crystals were not tried on coconuts to see if they would reproduce the cadang-cadang symptoms.

On the other hand, Ocfemia and Bustrillos (1957) announced that they found under the electron microscope "numerous uniform nearly spherical bodies" in the juices from the cabbage and opened leaves of infected coconut trees, which are presumed to be virus particles. These particles obtained as they were from crude preparations, may just as well be inert protoplasmic inclusions or artifacts. The evidence is further weakened by the fact that no parallel preparation was made from healthy trees outside the Bicol region.

2. Results of studies on soils and fertilizers were interpreted to mean that the soil could not have been the cause of cadang-cadang. On this basis some people concluded that the cause could not be anything but a virus. Typical of this attitude is the following report of Professor G. C. Francispillai: "The scientists at the Guinobatan experiment station felt that cadang-cadang is due to a virus. This opinion was based on the results of subjecting diseased trees to different nutritional feeds. Upon treatment, the new leaves of the trees assumed much greater color and showed signs of life and vigor. However, the treated trees died much earlier than the untreated trees in the long run, indicating that the nutritional food administered to the infected trees was received by the virus". (Anonymous, 1960, p. 18).

Similarly, Dr. Edward T. Tyner, former visiting professor of soils at Los Baños, advanced the opinion that the cadang-cadang menace in the Bicol region is caused by a virus. He opined that the non-nutritional aspect of cadang-cadang appears to be verified by the fertilizer test of the Bureau of Plant Industry, since various nutrients have not arrested the infestation in infected coconuts (Anonymous, 1960, p. 26). On another occasion, Tyner (1959) commented, "On the basis of the observations of this survey, I am of the opinion that Cadang-cadang in the Bicol region is non-nutritional in nature. The occurrence of Cadang-cadang on undulating relatively mature strongly acidic laterized upland soils, rolling to strongly rolling, moderate to weakly developed moderately acidic laterized upland soils, youthful well-drained slightly acidic flood plain soils, and sandy calcareous coastal fringe soils virtually eliminates major and minor nutrient deficiencies as a causative agent in the incidence or severity of true Cadang-cadang."

What has apparently not occurred to many people is the possibility that failure of the sick plant to recover from the disease upon application of fertilizers could mean that the wrong fertilizers were used. Aggravating the disease with fertilizer application could further mean that the fertilizer skewed some factor or constituent of the soil. When Tyner mentioned *major* and *minor* elements, he obviously did not take into account the non-essential elements which when present could affect plants, probably in a negative way. However, the more serious objection to this line of argument is that after hastily dismissing the soil as a cause, he came to the conclusion that the disease is consequently caused by a virus. This trend of thinking inadvertently closes the door against other possible causes, like other pathogenic organisms, insects, and nematodes.

The situation is aggravated by the opinions expressed by certain virus exponents against other workers whose ideas differ from theirs. For example, Price (1957) argued, "The dissenters (of the virus theory), with few exceptions are those who have had little first-hand experience with the disease—who have viewed the problem from afar. They are like the blind men who examined the elephant and described the animal according to the part actually encountered by their groping hands." Again, Maramorosch (1961) claimed, "... in spite of all evidence to the contrary, a few people fanatically adhere to this hypothesis (nutritional im-

balance), although their own field trials and those of others completely failed to substantiate their claims."

## THE SYMPTOMS OF CADANG-CADANG

If there had been a clear-cut criterion or criteria for determining whether or not a tree is affected by cadang-cadang, many of the dubious claims might have been avoided. For instance, when Celino produced the "pale white to brown narrow dashes," the question could have been asked, was he right in interpreting them as identical with the "small and distinct water-soaked lesions"? For that matter, are the water-soaked lesions relevant to cadang-cadang?

Ocfemia's (1937) description of the disease which he thought indicated the points of similarity to virus diseases follows: "The most conspicuous symptom of the disease is the yellowing or chlorosis of the leaves. This symptom is one of the most common manifestations of virus diseases. The leaves of coconuts suffering from cadang-cadang show at first an abundance of yellowish translucent spots. The small translucent spots gradually turn yellow. On the pinnae of the younger leaves the spots are small; they are about a millimeter in diameter. The spots tend to enlarge until their diameters are 3-4 mm. . . ."

"Owing perhaps to the absence or reduction of chlorophyll the blades of the pinnae of the middle leaves dry out. Necrosis is another symptom of different mosaic or yellow form of virus diseases.

"As soon as yellowing of the pinnae becomes noticeable, no fruits are formed, although spathes may be produced in abundance..... In the bunchy-top of abaca, infected plants, rarely, if ever, fruit.

"Many of the roots of the diseased palms are discolored. In bunchy-top of abaca, it was suggested that the rotting of roots is a result of infection. . ."

"It may thus be seen that cadang-cadang of coconuts exhibits two of three general types of symptoms of virus diseases—chlorosis and necrosis. It also shows the stunting effect, one of the most important results of infection with virus diseases, and the effect on fruit bearing."

It may be recalled that chlorosis, necrosis, stunting and fail-

ure to fruit are not exclusive symptoms of virus diseases. Deficiencies of boron and manganese, to mention only two, likewise produce these effects.

The characterization of the disease has changed slightly since Ocfemia. However, while there was apparent certainty in Ocfemia's paper, the later workers did not exude too much confidence. Witness for instance Calica and Bigornia (1960): "Cadang-cadang disease of coconuts has been subjected to continuous study since 1949. This fact notwithstanding, it is still not possible to delineate the development of the disease in the coconut palm. There are two reasons: (1) the disease has not been transmitted experimentally, and (2) there is considerable variability in the response of individual trees to cadang-cadang infection. Thus, the disease can not be diagnosed authoritatively until after it has advanced considerably." Despite this admission, they suggested the following as the symptoms of cadang-cadang:

"1. The development of tiny, roughly circular, bright-yellow, translucent spots on the veins and on the tissues adjacent to the veins of young leaves mature enough to be dark-green in color.

"2. The development of characteristic yellow mottle on more mature leaves.

"3. The presence of numerous olivaceous spots, often referred to as water-soaked spots on the nether surface of mottled leaves.

"4. Prominent bronzing of veinlets from the middle and up to the apex of affected leaflets.

"5. Rounding and scarification of nuts with brown streaks or patches.

"6. Deterioration or rotting of the tips including the absorptive zone of the feeder rootlets.

"Not one of the six symptoms enumerated above is distinctly unique as to characterize the disease or to set it apart from other maladies of the coconut palm. On the contrary, all of these symptoms should be considered an essential part of the yellow mottle decline syndrome."

It will be noted that four out of six points considered were concerned with the leaves and could very well be various aspects or successive stages of the same process. In general they are the characters that workers use in deciding whether or not a tree is affected. The fifth criterion is usually inapplicable because the

young trees are not expected to fruit and those that are badly affected do not fruit at all. The sixth criterion is seldom if ever used because it is cumbersome to examine the roots. Besides this, there has not been a detailed study of the root system of healthy and cadang-cadang affected coconut trees which may serve as basis for distinction.

Of the four symptoms on the leaves, the water-soaked spots get greatest emphasis. Despite their protestations to the contrary, workers in the field subconsciously classify a tree as affected by cadang-cadang solely on the presence of water-soaked spots on its leaves. Disconcertingly, the water-soaked spots have been observed repeatedly on trees which are not affected by cadang-cadang. In fact they could be induced by the simple expedient of excising a seedling coconut from its food store (Velasco and Fertig, 1957). On the other hand, there are young trees in the Guinobatan Experiment Station which may be taken to be in the early stage of cadang-cadang decline but which do not possess water-soaked spots on their leaves. They have sparse crown and at a height of one meter, the leafscars on the trunk are very far apart.

These considerations emphasize the need for a more critical diagnostic symptom of cadang-cadang. However, success in the search for such a symptom may hinge on the ultimate determination of the nature and cause of the disease.

## THE SOIL AS A FACTOR IN CADANG-CADANG

Because right at the start the virus theory has obsessed most workers, very little has been done to explore other possible causes of cadang-cadang. Whatever little attention was given to the soil as a cause of the disease has been usually done to supply arguments to disprove the possibility. Thus, Reinking (1950) argued, "the presence of isolated very productive trees in areas of 90 to 100 per cent infection in San Miguel Island . . . would indicate that soil deficiency is not the cause of the disease."

In addition, Price (1957) related, "In Barrio Quitago, Guinobatan, there is a small plantation in which coconut trees were planted in pairs about 60 years ago. Today, there are pairs in which one of the trees is in the serious stage of yellow mottle decline while the other is apparently healthy." He used this to buttress his contention that cadang-cadang can not be due to soil deficiency or the presence of a toxic substance in the soil.

The latest report that the present writer received of Quitago is that all the trees which are still standing in this patch are either dead or dying of cadang-cadang. The same is true in San Miguel Island.

However, even if the putatively resistant trees had not died so soon, it would still seem that the argument has an inherent weakness. The healthy trees in a field of 90-100 per cent "infection" do not necessarily imply that soil abnormality is not the cause of the disease. As has been emphasized earlier, coconut trees produced as they have been by cross pollination are highly heterozygous. It is to be expected that their response to a particular environmental factor—be it a pathogenic organism or an unfavorable soil constituent—would be widely divergent. For example, Velasco *et al.* (1960) reported that of the four plants they raised in sand culture without potassium, one plant became most adversely affected in one year after the start of treatment. On the other hand, another plant did not seem to suffer from lack of potassium even at the end of the experiment, or four years after the start of treatment.

To further eliminate the soil from the cadang-cadang picture, Price (1957) observed that "there is no evidence that other crop plants or weeds in the Bicol area are seriously affected by nutrient dificiency or toxicity. Abaca, citrus, rice and other crops grow well on land devastated of coconut trees by cadang-cadang."

Despite the arguments tending to eliminate the soil as a cause of cadang-cadang, the writer and his colleagues decided to explore the soil because of the following observations: (1) Cadang-cadang varies in severity, depending upon the locality or kind of soil. (2) It tends to be partial to old leaves. (3) Several species of plants exhibit unhealthy conditions and chronic die-back. And (4) preliminary observations indicate that when transplanted to good soil, coconuts may recover from cadang-cadang.

1. Cadang-cadang is most serious in places immediately surrounding Mayon Volcano and Mount Isarog, (fig. 1) especially in black soil which tends to be waterlogged. Here the coconuts may die even before they reach a height of five meters. In elevated places of the Mayon area, especially those of the brown to red soil, coconuts may grow beyond ten meters before they come down with cadang-cadang.

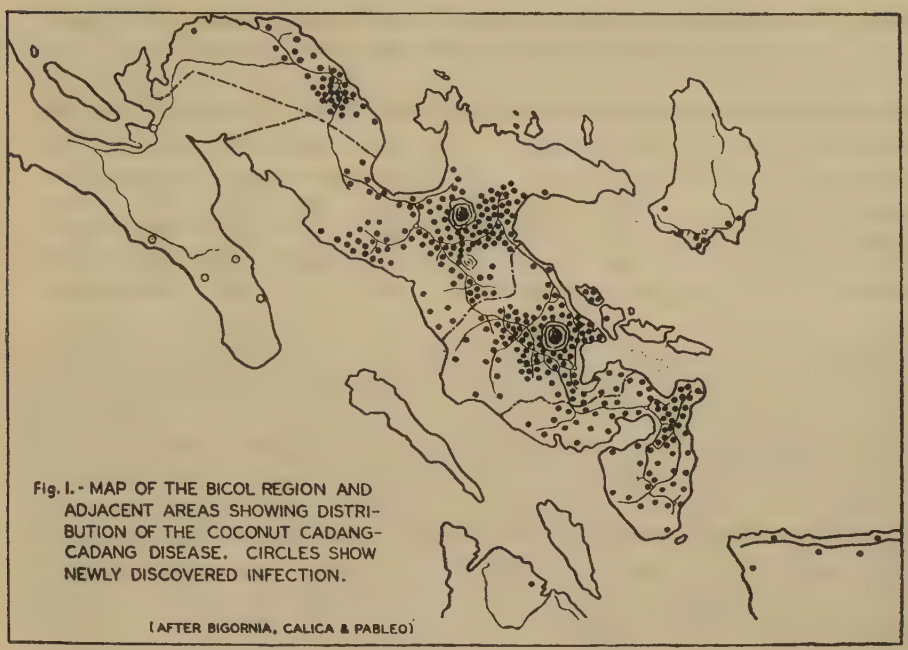

Fig. 1.- MAP OF THE BICOL REGION AND ADJACENT AREAS SHOWING DISTRIBUTION OF THE COCONUT CADANG-CADANG DISEASE. CIRCLES SHOW NEWLY DISCOVERED INFECTION.

(AFTER BIGORNIA, CALICA & PABLEO)

In Baao and Iriga, Camarines Sur and in Pilar and Castilla, Sorsogon, coconuts may grow to almost 20 meters before they die of cadang-cadang.

The strip survey of the Guinobatan Experiment Station showed that the percentages of cadang-cadang affected trees varied greatly from place to place. In general, infestation is heavier in Camarines Sur and Albay than in Camarines Norte and Sorsogon (table 1).

In the epidemiological plots of the Guinobatan group, the progress of cadang-cadang was most rapid in plots 1, 4 and 5 and very slow in plots 2 and 3 (table 2).

The coconut trees along the road from Bato Balani to Jose Panganiban, Camarines Norte are very healthy, while a few kilometers away, in Daet and Labo, trees are dying of cadang-cadang. If the cause of the disease is as virulent a pathogen as it has been claimed to be so that it can (according to present claims) reach up to Pagbilao, Quezon, what has been preventing it from covering the few kilometers to Bato Balani?

2. In general, the taller the coconut tree, the more likely it

TABLE 1.—*Per cent of disease incidence in the Bicol Provinces from* 1951-1959 (*After Bigornia, Calica and Pableo,* 1960)

| PROVINCE | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 |
|---|---|---|---|---|---|---|---|---|
| Camarines Norte | 7.0 | 26.1 | 29.6 | 32.6 | 39.9 | 31.3 | 33.5 | 33.8 |
| Camarines Sur | 5.0 | 21.5 | 27.4 | 28.6 | 43.3 | 53.3 | 62.3 | 61.7 |
| Albay | 19.0 | 37.0 | 48.0 | 56.6 | 44.3 | 48.1 | 55.3 | 51.8 |
| Sorsogon | 11.0 | 19.8 | 29.0 | 23.0 | 20.7 | 40.3 | 32.3 | 31.3 |
| Average | 10.5 | 26.1 | 33.5 | 35.2 | 37.1 | 43.3 | 45.9 | 44.6 |

TABLE 2.—*Percentages of cadang-cadang in epidemiology plots* (*Adapted from Bigornia,* 1954)

| DATE | PLOT I | PLOT II | PLOT III | PLOT IV | PLOT V |
|---|---|---|---|---|---|
| Sept. - Nov. '51 | 0.6 | 0.8 | 1.0 | 1.2 | — |
| June - Aug. '52 | 18.8 | 4.4 | 4.0 | 13.2 | 59.2 |
| Sept. - Nov. '52 | 19.6 | 3.8 | 4.8 | 14.2 | 61.1 |
| June - Aug. '53 | 24.2 | 4.5 | 6.3 | 18.9 | 66.1 |

will come down with cadang-cadang. In groves where young trees are interplanted among old ones, it is often seen that the latter are either dead or dying of cadang-cadang, while the former are apparently healthy and fruiting.

The old leaves of cadang-cadang-affected trees exhibit almost exclusively the water-soaked specks and the brown spots. The young leaves remain dark green even in the terminal phases of the decline.

In well-drained places, the leafscars on the trunk of cadang-cadang coconuts at a height of one to three meters are very far apart (42 cm. every 6 leafscars as against 27 cm. every 6 leafscars in Laguna). On the other hand, at 10 meters and beyond, the leafscars are very close together. It would seem that a certain factor of the environment—probably a constituent of the soil—when not yet accumulated in excess, has a stimulating effect

on growth; when in excess, it retards growth and kills the plant. It is probable that the growth inhibiting effect of this constituent is largely exerted through a disruption in the water economy of the plant. As the plant grows taller, greater energy is needed to raise water from the roots to the leaves; hence, the accentuated detrimental effect of the impaired water supply among tall plants.

The rotting of root tips may be an early manifestation of the detrimental soil constituent. Figure 2 shows the root tips of a two-year old coconut in the Guinobatan Experiment Station. The

Fig. 2.—*"Pencil roots" of a two-year old coconut grown in the Guinobatan Experiment Station. Root-tips rot and root branches arise, only to have their tips rot in turn. The leaves of this plant look very normal.*

tips rot and branches arise farther back of it. They grow a short distance before their tips rot in turn, and the process is repeated. This rotting of the root tips can be expected to reduce the water supply in the plant.

3. When Price (1957) observed that abaca, citrus, rice and other crops grow well on land devastated of coconut trees by cadang-cadang, he probably missed the early signs of unhealthiness

or he did not have a chance to observe the plants long enough. The writer observed that the big Tangongon abaca variety of Davao does not grow very tall in Bicol. Also, during short periods of drought, abaca leaves dry up so badly that they give the impression of general scorching. Abaca may be suffering from a disrupted water economy in a milder degree than coconuts.

Citrus plants may do apparently well in a young orchard but in five to ten years, trees start to show a mild decline consisting of cholorosis of old leaves and die-back of the taller branches. When the writer visited the Guinobatan Experiment Station for the first time in 1950, there were citrus trees on one lot of the station bordering the highway. The trees were about four meters tall and normally fruiting. There was occasional mottling of leaves but this was not alarming. Since then the trees have been dying off and in 1959, when the Station management decided to bulldoze the place in order to give way to coconuts, there were only a few citrus trees remaining. The citrus trees in San Miguel Island are also dying, and those which are in the final stages of decline are severely chlorotic.

Theer are many species of plants in Bicol like *Ageratum, Elephantopus, Stachytarpeta,* green pepper and tomatoes, which develop cupped leaves; others like citrus, black pepper and soybeans have chlorotic leaves. Die-back is exhibited by tree species like anii, citrus, lanzones, star apple, nangka and tamarind (fig. 3 to 8).

4. Coconut trees in the mild stage of the decline were balled and transplanted to Los Baños soil contained in a concrete tank located at Pili Agricultural School. Although the transplants have been barely one year in Los Baños soil, the newly produced leaves are long, pliant and healthy. This may be a good indication of recovery.

In order to identify the suspected abnormal constituent of the soil in the cadang-cadang area, the writer and his colleagues have been comparing the physical and chemical properties of Bicol soils with those of Quezon and Laguna. They first demonstrated that copper in this area was generally low and about three-fifths of the level in the soils of Quezon and Laguna (Velasco, 1957; Velasco, Palmquist and Mamawal, 1957). They also demonstrated that there was generally a high level of aluminum in the Bicol area (3 to 6 times those of Quezon and Laguna) and suggested that it could be toxic to many plants (Velasco, *et al.*, 1959; 1959a).

Fig. 3.—*Anii* (Erythrina fusca *Lour.*) *grown as shade for abaca at the Guinobatan Experiment Station. The trees had been suffering from chronic die-back. Afterwards, they all got blighted simultaneously.*

Fig. 4.—*Nangka at the Camarines Sur National Agricultural school* (*Pili*) *suffering from chronic die-back.*

Fig. 5.—*Tomato growing in a backyard in Legaspi City. The leaves are cupped, reduced. and frizzled. The very young leaves are chlorotic.*

Fig. 6.—*Green pepper at the Guinobatan Experiment Station. Note the cupped leaves which create a general impression that the plant has not been getting enough water.*

Fig. 7.—*Citrus growing at the Guinobatan Experiment Station. Note the severe dying back of twigs and the apparently more healthy growth at the base.*

Follow-up experiments to find if affected coconuts could be cured by copper treatments did not yield very encouraging results. There was apparent decrease in the premature drop of nuts with treatment of 2 per cent copper sulfate solution in the clasping leaf-bases. However, the sparse crown did not seem to grow more dense. In another experiment, Bicol soil in pots treated with copper sulfate and grown to tomatoes as test plants was not significantly better than Bicol soil alone. The tomatoes, at two months of age developed chlorosis just like those grown in Bicol soil alone, although the appearance of chlorosis was somewhat delayed. It would seem that if copper were deficient at all, it is not the critical factor that elicits cadang-cadang. The beneficial effects of

Fig. 8.—*Star apple at the Camarines Sur National Agricultural School (Pili) with diminutive leaves at a height of about four meters. Leaves on the lower branches are big.*

added copper is being masked by the effects of something that is more directly related to cadang-cadang.

About a year ago, attempts were made to increase the level of aluminum around the base of healthy coconut trees. It is too early to expect the appearance of cadang-cadang symptoms and the tests are still being continued.

In the meantime soil extracts were fractionated according to Noyes' scheme of qualitative analysis. The fractions were converted to their chlorides and diluted to 15 milligrams of total solids per milliliter. The solution was adjusted to pH 5.5 and applied to Lantana growing in sand at the rate of 15 milliliters every

week. Plants in the combined fraction of the alkaline earths and alkalies soon died. Even the replants in this treatment did not survive.

Further verification with *Ipomea triloba* seedlings showed that the toxic substance in the Bicol soil is a member of the alkaline earths. Its behavior in culture tests was similar to strontium and, in fact, this element was demonstrated in the extracts of Bicol soil by its characteristic oxalate crysal.

The writer and his colleagues are running culture experiments and conducting more analysis of soil and plant materials in order to determine if strontium is related to the cadang-cadang problem.

The present discussions have attempted to show that the virus theory of cadang-cadang, although widely accepted, is based on weak evidence. Therefore, more attention should be given to certain factor or factors in the soil, as a possible cause of the disease.

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# MEASUREMENT OF POTENTIAL EVAPOTRANSPIRATION AS A BASIS FOR IRRIGATING CROPS [1/]

EFREN J. JESUITAS, A. P. AGLIBUT, and A. R. SANDOVAL [2/]

WITH FOUR TEXT FIGURES

**Potential evapotranspiration could be a good guide for the irrigation of upland crops since it indicates the maximum water requirement of the crop thereby minimizing, if not avoiding the danger of depriving plants of water.**

**The formulas derived by Thornthwaite and by Penman may be modified since both underestimated the value of potential evapotranspiration during the dry periods and overestimated it during the wet periods.**

The proper conservation and use of water supply is a major agricultural problem. Irrigation is being adopted to make certain that plants are not deprived of water throughout their development. However, without the knowledge of the water requirement of a crop, it is impossible to determine the extent by which plants should be subjected to irrigation. It is therefore important that the rates and amounts of evaporation and transpiration from land surface under different plant covers are determined.

During a rainfall, a part of the moisture retained in the soil evaporates directly to the air and a part is taken in by plants. Most of the water which enters the plant, however, is later transpired through its leaves and stems. The combination of evaporation from the soil surface and transpiration from the plants is called evapotranspiration.

There is a difference between the amount of water that is actually transpired and evaporated and that which would be transpired and evaporated if it were available. The former is called actual evapotranspiration and the latter, potential evapotranspiration.

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2/ The authors are grateful to: Mr. R. B. Villaroya for computing the analyses of variance and multiple correlation coefficients, Mr. R. B. Ganiron, for preparing the illustrations, and Miss A. B. Ocampo for helping in the preparation of the manuscript.

Potential evapotranspiration is defined by Thornthwaite (1946) as the amount of water which will be lost from a surface completely covered with vegetation if there is sufficient water available at all times for the use of this vegetation. Under this concept, as long as the plants completely cover the ground, are green, actively growing and uniform in height, and as long as water is not limiting, potential evapotranspiration is dependent only upon the weather elements.

Like actual evapotranspiration, potential evapotranspiration is also an important climatic element. It is primarily important in determining the water and/or irrigation requirement of any crop, such as the amount of water that should be used and when it is needed. Also, knowledge of its seasonal amount and variation is important in precipitation studies so that one can determine the periods of water deficiency and water surplus.

The first evapotranspirometer was conceived and introduced by Thornthwaite (1946) in 1946 for the purpose of solving the problem of water use by plants under continuous optimum soil moisture conditions. This instrument, however, is made from expensive and elaborate materials, and it has to be operated by trained technicians. These are probably the reasons why no previous potential evapotranspiration study had been made in the tropical regions.

Later, Mather (1951) modified Thornthwaite's instrument and developed a simple evapotranspirometer which can be made from inexpensive, even second hand, and readily available materials.

Because it is impractical to install evapotranspirometers in many localities of the world, formulas have been proposed to estimate potential evapotranspiration. The formulas developed by Penman and Thornthwaite are gaining universal popularity. These, however, were developed in the temperate regions, where the climatic conditions are essentially different from those of the tropical regions, like the Philippines. Since there is as yet no assurance that the formulas which had been derived from the conditions under the middle latitudes would apply to the tropics, their applicability in the Philippines should be studied.

This study was undertaken to measure the potential evapotranspiration at the U.P. College of Agriculture with upland rice as plant indicator, and to test the applicability of the Penman and Thornthwaite formulas by comparing the computed values with the observed potential evapotranspiration of upland rice.

This report includes the results from two seasons: the first, from December 16, 1958 to April 16, 1959 and the second, from May 16 to September 16, 1959.

## MATERIALS AND METHODS

*Installation of apparatus.* The apparatus was installed in a level lot within the new College Weather Station (fig. 1). Based

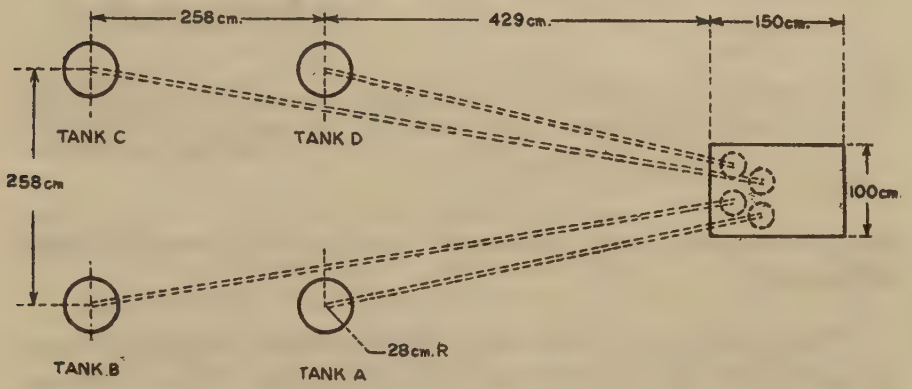


Fig. 1.—*Diagrammatic sketch of the evapotranspirometers (top view).*

on Mather's (1951) design, it consisted of four evapotranspirometer tanks 55 centimeters high. These tanks were made from ordinary gasoline drums. The tanks were placed in holes 47 centimeters deep. In the bottom of each tank was placed gravel about four centimeters thick and filled with the soil removed from the holes. The tanks were spaced 200 centimeters from each other (fig. 2). A wire mesh was placed at the bottom outlet of each tank under the gravel to prevent the clogging of the drainage pipe (D), which is 3/4 inch in diameter. The drainage pipe led to the overflow chamber set 400 centimeters from tank A. The chamber was made of soldered galvanized iron sheets and provided with cover to prevent water or soil from getting in the four one-gallon catch cans.

*Operation.* After the apparatus was installed, the 225-square meter buffer area around the tanks was tilled. The soil in the tanks was watered daily for 10 days to allow it to settle. After the soil in the tanks and in the buffer area was properly prepared, upland

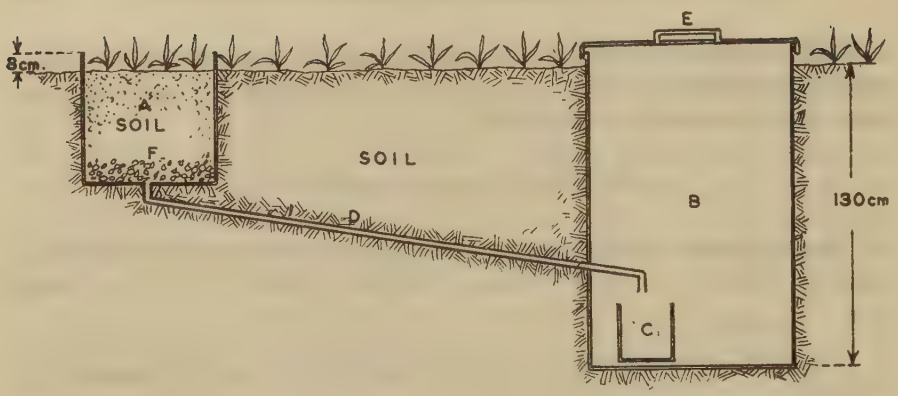


Fig. 2.—*Diagrammatic sketch of an evapotranspirometer (cross section) showing A) evapotranspirometer tank, B) overflow chamber, C) catch can, D), 3/4 inch pipe E) handle of cover of the overflow chamber, and F) layer of gravel.*

rice, (*Oryza sativa* var. Azucena)[3/] was planted in rows 20 centimeters apart.

The tanks were watered daily with measured amounts of water. The percolates in the catch cans were measured with a graduated cylinder before the tanks were watered with the measured amounts of water for the day. The daily percolates were measured and used for watering the tanks to minimize the loss of soil fertility. The amounts of water added and the percolates were recorded every morning at the same hour. Unless it rained, the buffer area was also watered daily to bring the soil moisture content as close as possible to field capacity similar to the moisture content of the soil in the tanks. This was necessary in order to minimize, if not avoid, the advection effect. As the experiment progressed, cultivation and weeding were performed. No fertilizer was applied in the tanks and buffer area.

*Weather observation.* In gathering weather data, precipitation, mean temperature, relative humidity, wind speed, and per cent possible sunshine were considered. These were necessary in the determination of potential evapotranspiration by the formulas. Weather observation took place at 8 every morning.

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3/ Planting seeds were provided by the Division of Plant Breeding, Department of Agronomy.

*Computation of potential evapotranspiration by formulas.* The method of computation proposed by Thornthwaite (1948) makes use of an empirical formula, which considers temperature and latitude as the primary variables in estimating potential evapotranspiration. His equation is given as follows:

$$e = 1.6\ (10t/\mathrm{I})^{a}$$

where

$e$ is the unadjusted monthly potential evapotranspiration in cm; $t$ is the mean monthly temperature in °C; I is the heat index which is a constant for a given locality and is equal to the sum of 12 monthly index values i; $i$ is the function of the monthly normal temperatures; and $a$ is an empirically determined exponent which is a function of I. The values of $i$ and $a$ are obtained as follows:

$$i = (t/5)^{1.514}$$

$$a = 0.000000675(\mathrm{I})^{3} - 0.0000771(\mathrm{I})^{2} + 0.01791\mathrm{I} + 0.49239$$

For value of $e$, Thornthwaite (1946) stated;

> "The formula gives unadjusted rates of potential evapotranspiration. Since the number of days in a month ranges from 28 to 31 (nearly 11 per cent), and the number of hours in a day between sunrise and sunset, when evatranspiration principally takes place, varies with the season and latitude, it becomes necessary to reduce or increase the unadjusted rates by a factor that varies with the month and with latitude."

Thornthwaite and Mather (1957) prepared a table for this correction factor.

By considering the energy balance of evaporation, Penman as cited by van Bavel (1956), derived an equation expressing potential evapotranspiration in terms of duration of sunshine, mean temperature, vapor pressure, and mean wind speed. His procedure is as follows (see next page):

For the value of potential evapotranspiration, Penman suggested the use of an empirical factor of 0.7 to account for the difference between open water and vegetated cover. In the computation, however, the factor 1.0 was used.

*Determination of the measured potential evapotranspiration.* Measured daily potential evapotranspiration is equal to the amount of water added plus any rainfall minus the amount of water that percolated. Potential evapotranspiration for the season equals the

$$E_T = \frac{\Delta H + 0.27 E_a}{\Delta + 0.27}$$

where

$$E_a = 0.35(e_a - e_d)(1.0 + 0.0098u_2) \text{ mm./day}$$

$$H = R(1-r)(0.18 + 0.55n/N - \sigma T_a^4(0.56 - 0.92\sqrt{e_d})(0.10 + 0.90n/N$$

$$\Delta = \frac{de}{dt}\Big| T_a$$

$E_T$ is the evapotranspiration in mm. per day; H and $E_a$ are auxiliary quantities; $e_a$ is the saturation vapor pressure in mm. per day; $e_d$ is the actual vapor pressure of air in mm. Hg; $u_2$ is the wind speed at two meters above the ground in miles per day $R_a$ is the mean monthly extraterrestrial radiation in mm. per day; r is the reflection coefficient which Penman suggested to take 0.05 as the value which applies to open water; n/N is the percent possible sunshine; $\sigma$ is the Boltzman constant, which is equal to $2.01 \times 10$ mm. per day; $T_a$ is the air temperature.

sum of the daily potential evapotranspiration.

## RESULTS AND DISCUSSION

The installation of the four tanks was completed on December 4, 1958. Daily observations began from December 16, 1958 through April 16, 1959 for the first (dry season) planting. In each planting, observation began when 75 per cent of the seeds had germinated, and terminated when the crops were harvested.

Data showed that palay needed an average of 6.1 mm. daily, or a total of 730.8 mm. from planting to harvesting during the dry season, and an average of 3.7 mm. daily, or a total of 458.3 mm. during the wet season.

Some of the measured potential evapotranspiration for the first planting were extremely high. For instance, on March 15, 1959, the measured value was 10.4 mm. and on February 27, 1959, it was 9.8 mm. These could be attributed to the water holding capacity

of the soil. This sudden rise in value of potential evapotranspiration occurred only when rains fell because it took sometime for the rain water that entered the tank to have complete percolation. Not all water in excess of plant use and evaporation from the soil had percolated during the required time prior to observation. Consequently, this resulted in the apparent increased amount of water added, and with small percolation, the measured potential evapotranspiration became high. This was evidenced by the abrupt decrease of the measured value for the day following rain.

In table 1, it can be noted that the variability of the measured potential evapotranspiration among the tanks was greater during the dry season planting than during the wet season. This prob-

TABLE 1.—*Cumulative measured and computed potential evapotranspiration from two seasons of planting*

| POTENTIAL EVAPOTRANSPIRATION | PLANTING SEASON | |
|---|---|---|
| | First (dry) | Second (wet) |
| A. Measured by Evapotranspirometer | | |
| | *mm.* | *mm.* |
| A | 685.0 | 455.3 |
| B | 746.0 | 447.9 |
| C | 887.0 | 457.9 |
| D | 616.0 | 445.3 |
| Average | 730.8 | 451.3 |

ably is due to the uneven growth of the plants in the tanks as evidenced by the weights of the vegetative cover at harvest. Although the tanks were given the same attention, a variation was noted, caused most likely by the uneven fertility of the field, which was previously planted with corn, and by the advection effect which may have affected the observation since the site only had an area of 225 square meters.

The second (wet season) planting did not show much variation; instead, several negative values were observed. These negative values can be explained by the water retention capacity of the soil. As previously explained, rain water that entered the tank took sometime before full percolation was obtained. The water which was not used by the plants was still held by the soil and did not evaporate, thus making the percolation for the day much less compared to the amount received by the tanks. This resulted in the high value of potential evapotranspiration. However, in the

following day, this excess water percolated, thus increasing the amount of water received by the tanks. This phenomenon resulted in a negative value which Mather (1951) defines as "a fiction resulting from the daily bookkeeping procedure used on evapotranspirometer tanks."

Tables 2 and 3 show the average weights of grain and straw

TABLE 2.—*Average weights of grain and straw and number of panicles from first (dry season) planting* [a]

| HARVESTED FROM | FRESH WEIGHT | | AIR DRY WEIGHT | | NUMBER OF PANICLES |
|---|---|---|---|---|---|
| | Grain | Vegetative | Grain | Vegetative | |
| Evapotranspirometer | *gm.* | *gm.* | *gm.* | *gm.* | |
| A | 56.3 | 257.6 | 48.3 | 201.2 | 59 |
| B | 61.4 | 451.2 | 55.0 | 212.3 | 62 |
| C | 75.3 | 684.6 | 67.2 | 236.3 | 60 |
| D | 34.6 | 263.7 | 30.1 | 166.0 | 45 |
| Buffer area sample | | | | | |
| 1 | 72.1 | 250.2 | 62.0 | 208.7 | 60 |
| 2 | 137.5 | 725.2 | 118.6 | 345.3 | 64 |
| 3 | 92.3 | 677.5 | 153.1 | 272.5 | 59 |
| 4 | 106.1 | 682.0 | 90.7 | 280.8 | 63 |

[a/] Data from the buffer were obtained from random samples each as big as the area of each tank.

TABLE 3.—*Average weights of grain and straw and number of panicles from second (wet season) planting* [a/]

| HARVESTED FROM | FRESH WEIGHT | | AIR DRY WEIGHT | | NUMBER OF PANICLES |
|---|---|---|---|---|---|
| | Grain | Vegetative | Grain | Vegetative | |
| Evapotranspirometer | *gm.* | *gm.* | *gm.* | *gm.* | |
| A | 97.0 | 799.0 | 83.1 | 336.7 | 60 |
| B | 94.0 | 767.0 | 78.1 | 335.9 | 58 |
| C | 83.1 | 627.7 | 67.1 | 308.3 | 54 |
| D | 90.2 | 574.1 | 77.1 | 257.6 | 43 |
| Buffer area sample | | | | | |
| 1 | 136.4 | 572.2 | 100.2 | 230.0 | 43 |
| 2 | 110.6 | 743.4 | 88.5 | 319.7 | 44 |
| 3 | 113.9 | 700.1 | 88.5 | 306.1 | 52 |
| 4 | 161.1 | 1009.a | 127.5 | 428.2 | 56 |

[a/] Data from the buffer area were obtained from random samples each as big as the area of each tank.

from the first and second plantings, respectively. There was a wide variation of yield among the tanks. However, the yield in each tanks and the buffer area, there was a significant variation of the evapotranspiration. Although the same attention was given to the tank tended to be directly proportional to the observed potential weight of the vegetative growth or cover.

The daily cumulative values of the measured and computed po-

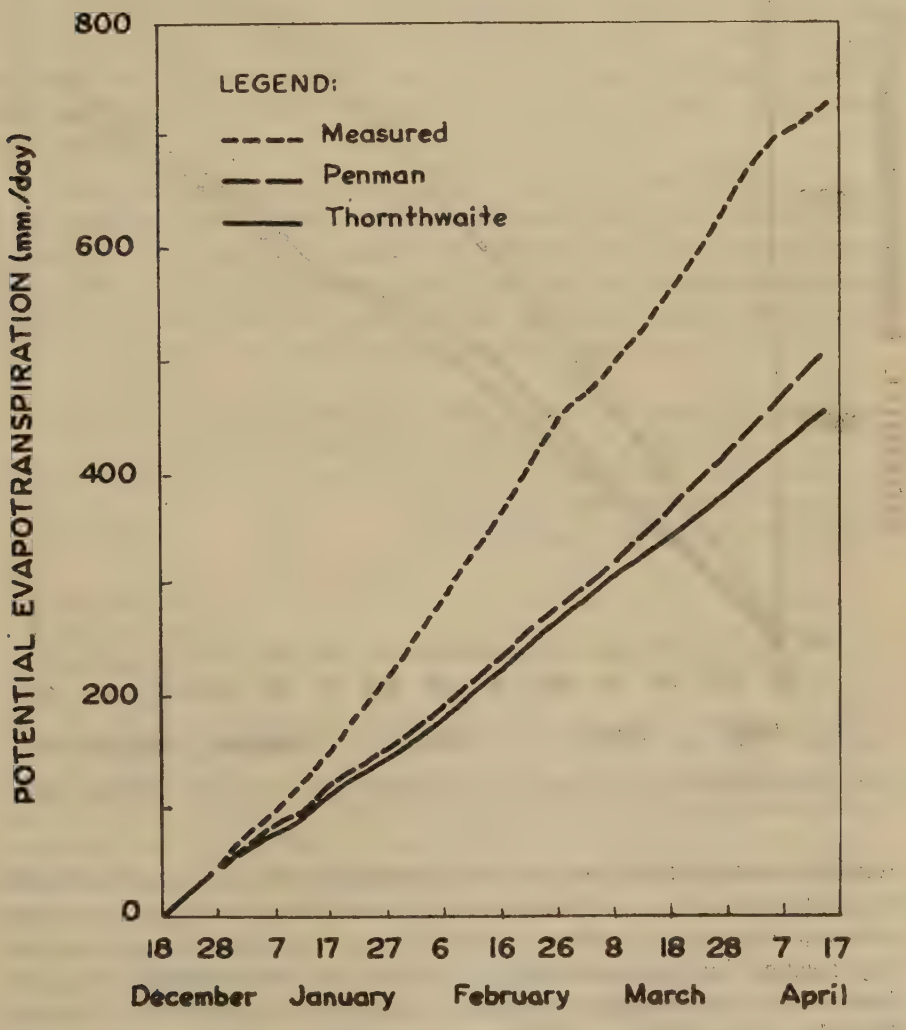


Fig. 3.—*Measured and computed potential evapotranspiration. (First planting.)*

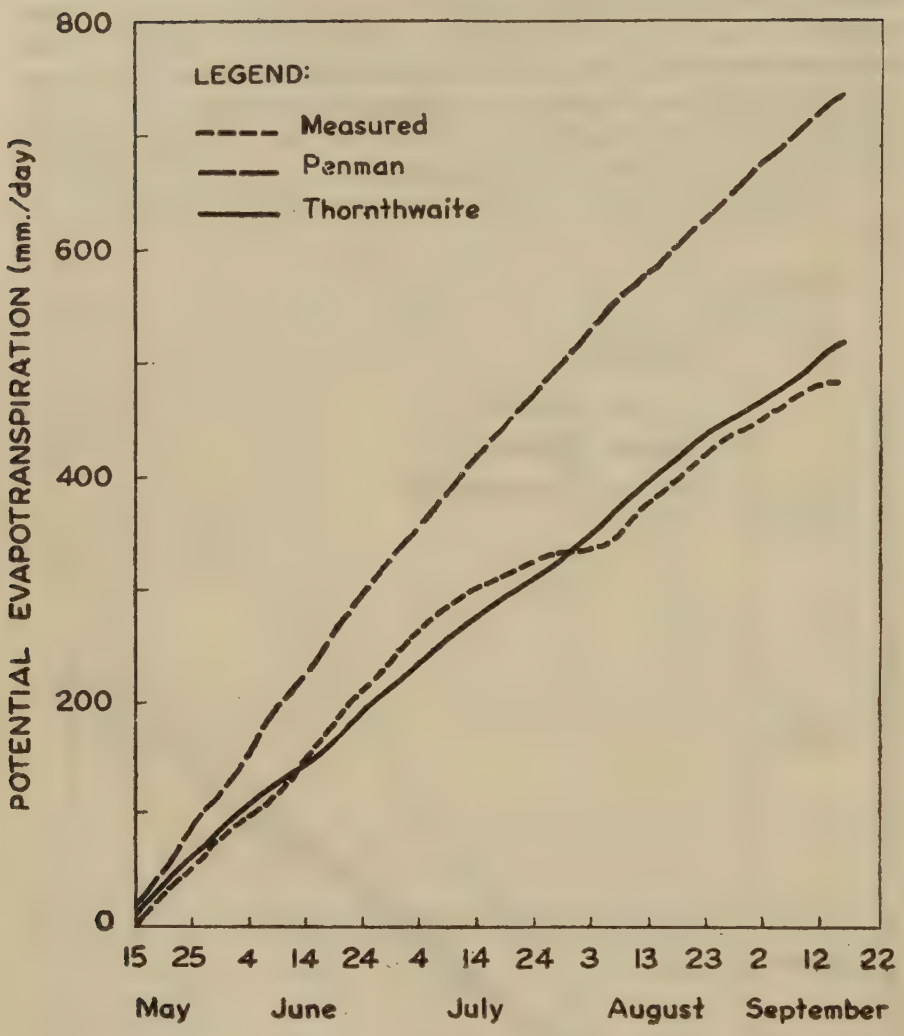


Fig. 4.—*Measured and computed potential evapotranspiration (Second planting).*

tential evapotranspiration for both plantings are shown graphically in figures 3 and 4. A comparison showed that both the formulas underestimated the observed potential evapotranspiration during the dry season, but overestimated it during the wet season. The behavior of Thornthwaite's formula was also observed at Toronto, Canada, and at Norman Wells, Canada by Sanderson (1950). In her experiments, she found that the computed values overestimated

the measured results during the wet periods and underestimated them during the dry periods. This shows that the formulas derived by Thornthwaite and by Penman have to be modified to apply safely in the tropics.

The result of this study showed that potential evapotranspiration of upland rice, variety Azucena, was low during the first week after germination and during the week before harvesting when the transpiration of plants was at its minimum. The potential evapotranspiration of plants was at its maximum from a few weeks before booting up to the last week before harvesting. Irrigation requirements of upland rice as indicated by potential evapotranspiration show a value which is lower during the wet than during the dry season.

Since the weather elements to be compared with potential evapotranspiration are closely related with each other, the simple linear correlation test may not apply. The partial correlation coefficient, therefore, was taken to uncover the effect of one element to another which may alter the true relationship that may exist between one weather element and potential evapotranspiration.

TABLE 4.—*Correlation coefficient of some weather elements with the measured potential evapotranspiration for both plantings*

| ELEMENT | PARTIAL CORRELATION COEFFICIENT | |
|---|---|---|
| | First Planting | Second Planting |
| Temperature | —0.332 | 0.673 |
| Relative Humidity | 0.097 | —0.043 |
| Wind speed | 0.714 | —0.557 |
| Per cent Sunshine | 0.479 | 0.514 |

It could be seen that during the first planting, the only weather element which gave a negative correlation was temperature, showing an inverse relation to potential evapotranspiration. Wind speed produces the highest partial correlation coefficient. This seems to indicate that potential evapotranspiration is more dependent on the rate of change of the mass of air passing through the evapotranspirometers.

As compared with the partial correlation coefficient of the wet season planting, wind speed has a negative value and temperature gives a high value of correlation coefficient. These values show that during the wet season, the rate and amount of potential evapo-

transpiration depend more on temperature than wind, sunshine, and relative humidity.

The probable cause of this kind of temperature behavior during the first planting was the advection effect which may have affected the observation. During the first planting, the land surrounding the evapotranspirometer site was vacant and dry. The mass of air passing through this land may have acquired its temperature such that when it reached the tank, the temperature and relative humidity were not yet uniform owing to the small size of the buffer area of the evapotranspirometer site.

It could also be noted that the mean temperature during the dry season is lower than that of the wet season. This could be explained by the fact that the dry season planting coincided with the warm months.

The multiple correlation for the first and second plantings are 0.5922 and 0.6791, respectively. The correlation coefficient for the former is significant at the 5 per cent level while that for the latter is significant at the 1 per cent level. This shows that potential evapotranspiration could be estimated and is dependent upon the weather element.

To determine which of the weather elements have the greatest effect on potential evapotranspiration, analyses of variance were made for the first and second plantings (tables 5 and 6). In the first planting, the wind speed had a significant effect on the potential evapotranspiration; in the second planting, it did not. The situation during the first planting may be attributed to the fact that the first planting coincided with the dry season, further proving the previous discussion of advection effect. Had the wind speed really affected potential evapotranspiration more than the other elements, it would have shown also in the second planting which coincided with the rainy season. Hence, the data indicated that all the weather elements observed are equally important in estimating potential evapotranspiration.

TABLE 7.—*Weekly total potential evapotranspiration and weekly average of the weather elements (First Planting)*

| DATE | TEMP. | REL. HUM. | WIND SPEED | % SUN-SHINE | POT. EVAPOTRANS. MEAS. | THORNWAITE | PENMAN |
|---|---|---|---|---|---|---|---|
| Dec. 18-24 | 26.00 | 74.71 | 2.30 | 51.71 | 26.1 | 25.7 | 27.5 |
| 25-31 | 25.20 | 71.00 | 2.34 | 68.28 | 32.8 | 23.1 | 27.4 |
| Jan. 1-7 | 25.91 | 80.57 | 3.20 | 54.57 | 33.6 | 26.6 | 23.7 |
| 8-14 | 25.46 | 84.28 | 3.06 | 40.43 | 34.2 | 25.1 | 20.8 |
| 15-21 | 24.33 | 79.57 | 3.46 | 44.28 | 44.6 | 23.5 | 22.4 |
| 22-28 | 25.00 | 83.71 | 3.64 | 22.43 | 44.8 | 23.0 | 19.9 |
| Jan. 29-Feb. 4 | 25.94 | 82.57 | 3.43 | 50.00 | 42.3 | 27.7 | 26,0 |
| Feb. 5-11 | 25.87 | 79.00 | 3.29 | 52.28 | 54.2 | 27.0 | 27.9 |
| 12-18 | 26.47 | 78.71 | 3.86 | 59.71 | 52.9 | 30.1 | 31.1 |
| 19-25 | 26.64 | 79.71 | 3.46 | 67.71 | 53.7 | 30.8 | 31.5 |
| Feb. 26-Mar. 4 | 25.78 | 85.14 | 3.26 | 30.14 | 45.1 | 28.5 | 22.2 |
| Mar. 5-11 | 26.46 | 83.00 | 3.61 | 42.00 | 38.2 | 30.8 | 27.2 |
| 12-18 | 26.90 | 84.57 | 4.06 | 23.43 | 44.6 | 33.2 | 22.5 |
| 19-25 | 26.57 | 79.86 | 4.00 | 51.71 | 51.1 | 31.8 | 27.0 |
| 26-April 1 | 27.10 | 77.00 | 4.34 | 41.28 | 56.3 | 34.4 | 30.7 |
| April 2-8 | 27.50 | 79.14 | 3.94 | 36.29 | 40.6 | 36.5 | 30.3 |
| 9-15 | 28.46 | 77.14 | 4.14 | 43.43 | 32.0 | 42.3 | 34.3 |

*Analysis of Variance*

| SOURCE OF VARIANCE | D.F. | S.S. | M.S. | Computed F-Value |
|---|---|---|---|---|
| Regression on $X_1$, $X_2$, $X_3$, and $X_4$ | 4 | 768.73 | | |
| Regression on $X_2$, $X_3$, and $X_4$ | 3 | 567.25 | | |
| Regression on $X_1$ after $X_2$, $X_3$, and $X_4$ | 1 | 201.48 | 201.49 | 4.56 |
| Regression on $X_1$, $X_3$, and $X_4$ | 3 | 763.95 | | |
| Regression on $X_2$ after $X_1$, $X_3$, and $X_4$ | 1 | 4.78 | 4.78 | 4.11 |
| Regression on $X_1$, $X_2$, and $X_4$ | 3 | 111.90 | | |
| Regression on $X_3$ after $X_1$, $X_2$, and $X_3$ | 1 | 656.82 | 656.82 | 14.89a |

| | | | | |
|---|---|---|---|---|
| Regression on $X_1$, $X_2$, and $X_3$ | 3 | 607.65 | | |
| Regression on X1 after $X_1$, $X_2$, and $X_4$ | 1 | 161.05 | 161.05 | 3.65 |
| Error | 12 | 529.33 | 44.11 | |

a/ Significant at 1% level.

$Y = 13.081 - 4.928X1 - 0.198X2 - 16.62X3 - 0.327X4$

where —

$X_1$ — temperature
$X_2$ — relative humidity
$X_3$ — wind speed
$X_4$ — per cent sunshine

TABLE 8.—*Weekly total potentiai evapotranspiration and weekly average of the weather elements. (Second Planting).*

| DATE | TEMPE-RATURE | REL. HUM. | WIND SPEED | % SUN-SHINE | POT. EVAPOTRANS. MEAS. | THORNTH-WAITE | PENMAN |
|---|---|---|---|---|---|---|---|
| May 15-21 | 28.47 | 83.86 | 2.90 | 52.86 | 26.4 | 48.1 | 32.9 |
| May 22-28 | 29.64 | 80.43 | 2.91 | 51.57 | 36.5 | 51.0 | 26.5 |
| May 29-June 4 | 29.26 | 88.00 | 2.16 | 33.86 | 36.4 | 48.3 | 26.5 |
| June 5-11 | 29.24 | 79.57 | 2.38 | 41.71 | 31.3 | 48.4 | 31.4 |
| June 12-18 | 29.68 | 81.14 | 2.30 | 38.14 | 51.2 | 51.2 | 30.2 |
| June 19-25 | 29.30 | 81.28 | 2.74 | 56.14 | 40.8 | 49.1 | 33.5 |
| June 26-July 2 | 28.33 | 85.43 | 3.06 | 46.14 | 30.5 | 43.5 | 29.6 |
| July 3-9 | 27.90 | 84.28 | 1.01 | 43.00 | 35.0 | 40.9 | 30.1 |
| July 10-16 | 27.84 | 87.28 | 5.54 | 37.57 | 3.3 | 40.4 | 27.7 |
| July 17-23 | 27.77 | 88.00 | 2.10 | 41.28 | 9.6 | 40.0 | 27.0 |
| July 24-30 | 27.17 | 91.71 | 1.73 | 34.00 | 6.9 | 36.8 | 26.9 |
| July 31-Aug. 6 | 27.18 | 84.28 | 3.93 | 32.00 | —1.4 | 36.0 | 26.9 |
| Aug. 7-13 | 27.68 | 84.14 | 2.34 | 68.86 | 48.7 | 38.6 | 34.1 |
| Aug. 14-20 | 27.01 | 90.14 | 1.87 | 41.14 | —18.3 | 35.1 | 25.3 |
| Aug. 21-27 | 26.40 | 89.14 | 1.90 | 50.43 | 25.6 | 32.8 | 27.5 |
| Aug. 28-Sept. 3 | 26.76 | 87.57 | 4.36 | 28.28 | 15.0 | 33.5 | 23.8 |
| Sept. 4-10 | 26.43 | 90.00 | 2.04 | 46.43 | 20.4 | 31.2 | 26.9 |
| Sept. 11-16 | 27.33 | 84.67 | 2.48 | 60.33 | 19.7 | 36.7 | 28.8 |
| X | 27.9661 | 85.6067 | 2.6528 | 44.6522 | 25.2333 | | |

*Analysis of Variance*

| SOURCE OF VARIANCE | D.F. | S.S. | M.S. | Computed F-Value |
|---|---|---|---|---|
| Regression on $X_1, X_2, X_3, X_4$ | 4 | 2,619.99 | | |
| Regression on $X_2, X_3, X_4$ | 2 | 2,249.86 | | |
| Regression on $X_1$ after $X_2, X_3, X_4$ | 1 | 370.13 | 370.13 | 3.89 |
| Regression on $X_1, X_3, X_4$ | 3 | 2,603.94 | | |
| Regression on $X_2$ after $X_1, X_3, X_4$ | 1 | 16.05 | 16.05 | 0.17 |
| Regression on $X_1, X_2, X_4$ | 3 | 2,248.46 | | |
| Regression on $X_3$ after $X_1, X_2, X_4$ | 1 | 371.53 | 371.53 | 3.90 |
| Regression on $X_1, X_2, X_3$ | 3 | 2,313.46 | | |
| Regression on $X_4$ after $X_1, X_2, X_3$ | 1 | 306.53 | 306.53 | 3.22 |
| Error | 13 | 1,238.03 | 95.23 | |

$$Y = 136.10 + 6.9128X_1 - 0.4722X_2 - 4.7925X_3 + 0.4730X_4$$

where:

$X_1$ — temperature
$X_2$ — relative humidity
$X_3$ — wind speed
$X_4$ — percent sunshine

## CONCLUSIONS

1. Potential evapotranspiration could be a good guide for irrigating upland crops since it indicates the maximum water requirement of the crop, thereby minimizing, if not avoiding, the danger of depriving plants of water.

2. Since potential evapotranspiration is dependent upon the weather elements, it could be estimated by a formula using the different weather elements as the independent variables.

3. The formulas derived by Thornthwaite and Penman may be modified since both underestimated the measured value of potential evapotranspiration during the dry periods and overestimated it during the wet periods.

4. Disregarding the advection effect during the dry season planting, all the weather elements could be considered equally important in estimating potential evapotranspiration.

5. Further study, therefore, should be undertaken to determine further the relationship of the weather element to potential evapotranspiration.

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# THE FLOWERING RESPONSE OF LOWLAND RICE VARIETIES TO NATURAL PHOTOPERIOD [1/]

R. M. LANTICAN AND M. B. PARKER

WITH THREE TEXT FIGURES

**To determine the response of 345 foreign and 71 Philippine rice varieties to natural changes in day length in the Philippines, plantings were made at College, Laguna (latitude 14°N) in June, September, and January. A variety was classified as sensitive to photoperiod and temperature changes when the maximum range in its sowing-heading period exceeded 23 days.**

**Approximately 13 per cent and 52 per cent of the foreign and Philippine varieties, respectively, were classified as sensitive.**

**In the June planting, about 52 per cent of the sensitive varieties had a prolonged heading period which occurred in October. For the September planting, generally, flowering of the sensitive varieties occurred in the last two weeks of November and in the second and third week of December.**

Rice varieties may be classified on the basis of their flowering response to photoperiod. While some are indifferent to changing photoperiod, others are sensitive and are responsive to photo-induction.

The short-day varieties, once their required ripeness-to-flower stage has been attained, may be induced to flower precociously when exposed to the stimuli of shortened day length and probably, cooler temperature such as that prevailing during the latter part of the year. If flowering occurs before the plant would have accumulated adequate carbohydrates, it may consequently lead to a reduction in grain yield, as has been actually observed by Beachell (1943) and Misra (1954). In view of this, timely planting of photoperiod sensitive varieties is important in the growing of the crop.

This study was made to determine (1) the extent to which foreign and Philippine rice varieties may react to natural short photoperiods and (2) the periods when the majority of the short-day varieties would flower.

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1/ Central Experiment Station Contribution No. 2809.

## MATERIALS AND METHODS

This study was conducted at the Central Experiment Station, U.P. College of Agriculture (latitude 14°N).

A total of 416 lowland rice varieties were used. Of this, 345 were introductions received from the United States Department of Agriculture or directly from other countries, and 71 were local varieties collected from various regions in the Philippines. The foreign varieties were made up of both the *indica* and *japonica* types whereas the local ones were strictly of the *indica* type.

Three observational plantings were made, the first on June 21, 1956; the second on September 15, 1956; and the third on January 17, 1959.

Seeds were first germinated in cans. Two weeks later, they were transplanted in 3 1/2 meter long single row plots. The spacing employed was 40 cm. between rows and 20 cm. between hills. Practically the same treatment was given to all the plantings. No fertilizer was applied.

The date of flowering was taken for each variety when 50 per cent of the plants in the row had flowered.

## RESULTS AND DISCUSSION

For each variety, the maximum difference in sowing-heading interval among the three plantings was determined. The frequency of varieties falling under each range of difference is indicated in table 1.

A variety was considered photoperiod sensitive when the maximum deviation in its sowing-heading period has reached 24 days or above. This figure was arbitrarily chosen to represent, with a reasonable degree of certainty, those differences resulting from photoperiod influences.

Of the total number of entries from the U.S. and China, which together composed the majority of the introductions, 6.72 per cent and 18.45 per cent, respectively, were classified as sensitive. Taking the foreign varieties as a whole, 13.04 per cent showed sensitivity.

Among the 71 Philippine varieties, 52.11 per cent reacted to

TABLE 1.—*The distribution of Philippine and foreign varieties at given differences in sowing-heading period among the June, September and January plantings*

| PLACE OF ORIGIN | DIFFERENCE IN DAYS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ASIA | | | | | | | | | |
| Burma | 2 | | 1 | | 1 | | | | |
| China | 38 | 38 | 8 | 5 | 6 | 3 | 1 | 3 | 1 |
| Formosa | 8 | 3 | 3 | 1 | 1 | | | 1 | |
| India | 1 | 3 | | | 1 | | | | |
| Indonesia | 3 | 7 | 4 | 1 | 1 | | | | |
| Japan | 3 | 2 | | | | | | | |
| Korea | 2 | 1 | | | | | | | |
| Thailand | 2 | 2 | | | | | | | |
| Turkey | | 3 | | | | | | | |
| Others | | 3 | | | | | | | |
| CENTRAL AMERICA | | | | | | | | | |
| El Salvador | 6 | 1 | 1 | | | | | | |
| Haiti | 7 | 1 | | | | | | | |
| Puerto Rico | 4 | | | | | | | | |
| Others | 2 | 1 | | | | | | | |
| EUROPE | | | | | | | | | |
| Spain | | | | | | 1 | 6 | | |
| Others | 2 | | | | | | | | |
| SOUTH AMERICA | | | | | | | | | |
| Brazil | 4 | | | 2 | | | | | |
| British Guiana | | 1 | 2 | 1 | | | | | |
| Peru | 7 | 3 | 1 | | 1 | | | | |
| Venezuela | 6 | | | | | | | | |
| WEST AFRICA | 2 | 1 | 1 | | | | | | |
| UNITED STATES | 56 | 39 | 16 | 5 | 2 | | 1 | | |
| PHILIPPINES | 15 | 14 | 6 | 14 | 13 | 8 | 2 | | |

photoperiod. It is interesting to note that differences in heading date could be as much as seven weeks.

It will be observed that percentage-wise, more varieties in the local group reacted to the stimulus than in the introductions which originally came from more northern latitudes. It was conjectured that some of the foreign varieties may have actually been photoperiod sensitive but did not express the reaction on account of the absence of the required stimuli. On the other hand, the local varieties, which have long been established in the Islands, could have in the course of time differentiated in photoperiodic response, even at small fluctuations in day length and temperature.

Among the sensitive varieties, the differential heading period in the three plantings occurred in the manner indicated in table 2.

TABLE 2.—*Differential heading period of the sensitive varieties*

| CLASSIFICATION | FREQUENCY | |
|---|---|---|
| | Foreign | Local |
| I. Varieties with prolonged heading period in the June planting alone | 21 | 22 |
| II. Varieties with shorter heading period in the Sept. planting alone | 11 | 13 |
| III. Varieties with prolonged heading period in the Jan. planting alone | 7 | 1 |
| IV. Varieties with prolonged heading period in the Sept. planting alone | 4 | — |
| V. Varieties with shorter heading period in the Jan. planting alone | 2 | 1 |

In cases I and II, it is assumed that the varieties involved are responsive to short photoperiods and possibly low temperatures. The first case represents those which seemed to be exacting in their photoperiod requirements. When planted in June, the varieties showed a delayed flowering, which occurred only after October 1 when day length had approached the 12-hour duration. There is reason to believe that in the case of the January planting, the plants had an adequate period of growth to allow for the attainment of the ripeness-to-flower stage and a succeeding period of photo-induction prior to March 11, when day length had gone up again to approximately 12 hours. As in the September planting, early flowering resulted when the varieties were planted in January.

The varieties in the second case reacted only to the stimuli under which the September planting was exposed. Early flowering could have been caused by the interaction of the prevailing shorter photoperiod and lower temperature.

The reactions of varieties in cases III, IV, and V are believed to have been caused primarily by temperature differences.

In the June planting, flowering of the majority of the sensitive varieties occurred in the first three weeks of October as evidenced from the unimodal frequency distribution in figure 1. Regarding the September planting, heading of the sensitive varieties commenced

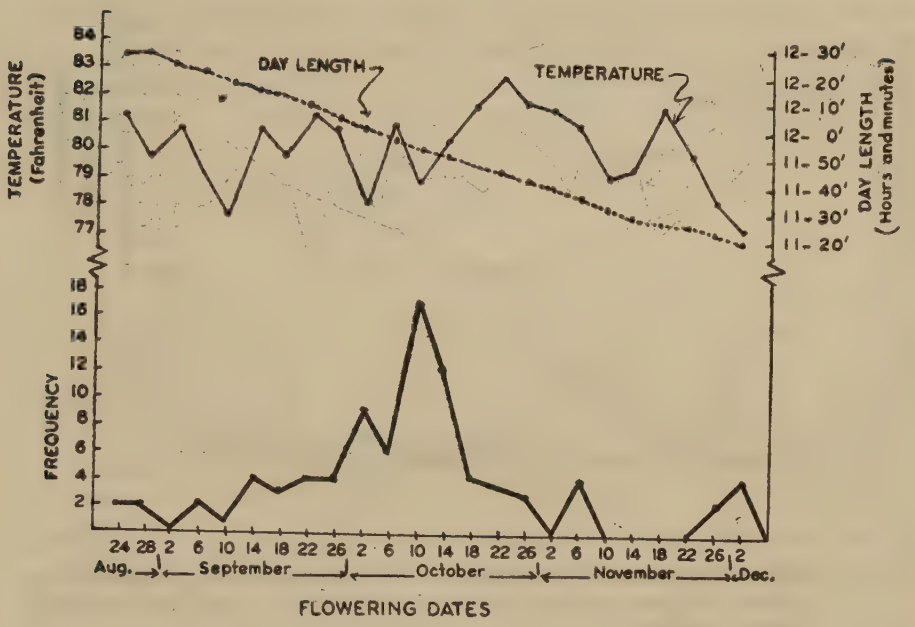


Fig. 1.—*Frequency distribution of the rice varieties and the prevailing day length and temperature during the flowering period of the June planting.*

from November 16 to January 17 (fig. 2) but the curve is more or less bimodal, one occurring at the last week of November and the other at the second and third week of December. Day length at the onset of flowering was 11 hours and 28 minutes. It progressively shortened to 11 hours and 17 minutes on December 22, the winter solstice. The frequency of flowering in the case of the January planting was widely distributed over a two month period in April and May (fig. 3).

A number of studies have demonstrated that changes in photoperiod may either delay (Sircar and Ghosh, 1947; Jagoe, 1952; Misra, 1955) or induce floral initiation (Sircar and Parija, 1945; Chandraratna, 1952; Sircar and Sen, 1953; Misra, 1954; Velasco and Manuel, 1955). But another factor which undoubtedly influences the sensitivity of varieties is temperature (Sircar and Ghosh, 1947; Siregar, 1954; Manuel and Velasco, 1957).

A knowledge of the photoperiod response of varieties is of significance in determining planting dates. On the one hand, if

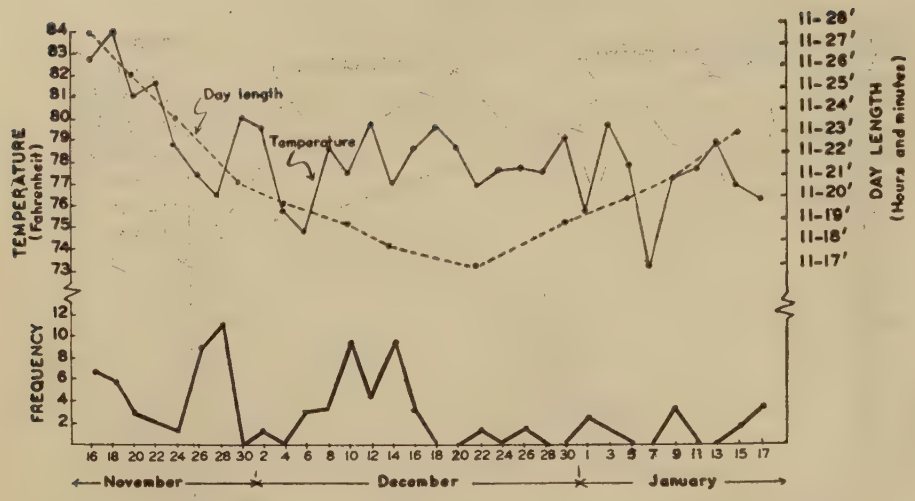


Fig. 2.—*Frequency distribution of the rice varieties and the prevailing day length and temperature during the flowering period of the September planting.*

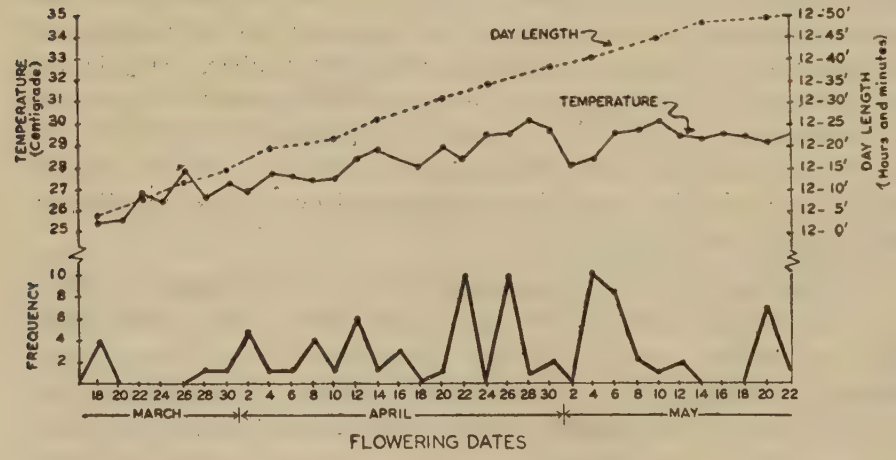


Fig. 3.—*Frequency distribution of the rice varieties and the prevailing day length and temperature during the flowering period of the January planting.*

flowering of sensitive varieties is induced to occur much earlier than it normally would due to late planting, grain yield may be markedly reduced, and on the other hand, if flowering is much delayed as a result of very early planting, the crop would be more exposed to environmental hazards aside from the fact that growing the crop will entail additional costs.

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# DETERMINATION OF THE DIGESTIBILITY OF FORAGE WITH PLANT CHROMOGENES AS INDICATOR [1/]

C. A. MABASA, JR., L. L. CALO,
A. B. LOPEZ, AND R. R. COVAR

**There is no appreciable difference in the digestion coefficient values obtained by the conventional method and the chromogen in the digestion studies on Alabang X,** Andropogon nodosus **(Willem) Nash, under pasture conditions. The grab method of sampling is less laborious and is as accurate as the total collection method.**

Digestibility is a very important criterion in evaluating the feeding value of forage, particularly pasture herbage which is an essential source of animal feed. No study concerning the digestibility of pasturage has yet been made locally. Under pasture conditions, there is no direct way of determining the digestibility of herbage because it is impossible to sample what is taken in by the animals during grazing.

Reid *et al.* (1950) proposed the use of plant chromogen as indicator for digestibility determination of forages under pasture conditions. The basic principle is expressed in the formula:

$$\text{Dig. Coef.} = 100 = (100 \text{ Concentration of chromogen in forage})$$

$$\text{Concentration of chromogen in feces}$$

Reid *et al.* (1952) reported that a complete extraction of chromogen from forage (especially at the mature stage) is difficult; thus, the applicability of the above formula is limited. However, they found out that there is a direct curvilinear relationship between digestibility and chromogen concentration in feces as presented by the equation:

$$\text{Dig.. coef.} = 32.74 + 0.0168\,x + 8.47 \text{ Log } x$$

where x is the unit of chromogen per gram feces (dry basis).

Digestibility of forage can easily be estmated with the above equation without the extraction of chromogen from the forage.

In digestion trial studies by Brisson *et al.* (1954), Soni *et al.* (1954), Bradley *et al.* (1956), Squibb *et al.* (1958) and Richards *et al.* (1959), the chromogen method was proved satisfactory in

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1/ Central Experiment Station Contribution No. 2810. Project No. 1358.

estimating the digestibility of herbage under grazing conditions. It eliminates the taking of a representative sample of the amount of forage grazed by the experimental animals, and utilizes the grab sampling technique which eliminates the use of collection bags.

This study was conducted in the Department of Animal Husbandry from October, 1958, to August, 1959 to: (1) test the accuracy of the chromogen indicator method of determining the digestibility of forage, (2) survey the feasibility of the use of the grab sampling technique in sampling feces, and (3) find out if any difference between grab samples taken in the morning and those taken in the afternoon under local conditions exists.

## MATERIALS AND METHODS

*Trial I.* A group of six steers were hand-fed twice a day (6 a.m .and 5 p.m.) with clipped forage of Alabang X, *Andropogon nodosus* (Willem.) Nash. The 14-day experimental period was divided into a 10-day preliminary period and a 4-day collection period. Daily total forage intake and fecal output were determined during the collection period. The sum of the morning and afternoon forage intake was considered as the total forage consumed and the feces collection for the day as the fecal output. For the analysis of plant chromogen, 300 g. (wet) of fecal samples were collected every morning and afternoon. Each collection consisted of total and grab samples. Total fecal samples were those from the fecal collection for the day, while grab fecal samples were those taken rectally at 6 a.m. and 5 p.m.

*Trial II.* Another group of six steers were hand-fed twice a day (6 a.m. and 5 p.m.) with clipped forage of Para grass, *Panicum purpurascens* Raddi. The techniques of sampling were the same as those in trial I.

*Trial III.* Three steers were allowed to graze on the lot of Alabang X, *Andropogon nodosus* (Willem.) Nash, which was adjacent to the lot where clipped forage used in trial I was taken. On the second day of the collection period, one of the steers was wounded by the barbed wire fence and had to be counted out. In determining the quantity of forage taken in by the experimental

animals in the pasture, the conventional method using chromic exide was followed (Gacula, *et al.*, 1960). Feces was collected in bags made of jute sacks provided with an inner lining of polyethelene plastic film.

The fecal sampling for chromogen determination was the same as that in trials I and II.

*Determination of chromogen.* All fecal samples for chromogen determination were placed in the refrigerator at 5°C. These samples were analyzed in the Nutrition Laboratory of Animal Husbandry, following the procedure set up by Reid *et al.* (1952). Fresh fecal samples of 5 to 7 g. were weighed out on qualitative filter paper and placed in the waring blender jar. About 175 ml. of 85 per cent acetone was added. The jar was covered with a vented cover lined with aluminum foil. To prevent a sudden overflowing of the contents, the switch of the blendor was flicked rapidly 2 to 3 times.

The blender was run continuously for 5 to 7 minutes to prevent leaking caused by the alternate blending and cooling of the sample. Meanwhile, the suction flask with Buchner funnel and Whatman No. 41 filter paper (9 cm.) moistened with a small amount of acetone solution was prepared.

After 7 minutes, the blendor was stopped, and the cover was rinsed with 85 per cent acetone solution. The contents were transferred to the Buchner funnel under gentle suction. The jar was rinsed with a small amount of the extracting solution.

After the sample was completely filtered, the filter paper with the residue was rolled up and returned to the blendor jar; the funnel was rinsed by pouring through it an 85 per cent acetone solution.

The extraction was repeated 2 to 3 times until a nearly clear extract was obtained. The clear extract was transferred to a 500 ml. volumetric flask and made up to volume with 85 per cent acetone solution. A 25 ml. aliquot of ti was filtered through Whatman No. I filter paper into a sample bottle provided with a tight cover and wrapped with carbon paper. The filtered samples were kept under refrigeration in the dark until they were read in the Beckman Spectrophotometer DU Model.

## RESULTS AND DISCUSSION

*Trial I.* No significant difference was observed between digestion coefficients of Alabang X, *Andropogon nodosus* (Willem.)

Nash, obtained by the conventional method and by the chromogen (total collection) method. The mean for the conventional method was 52.20 -|- 2.15 per cent and that for the chromogen method was 51.58 -|- 1.26 per cent. The small difference shows that the chromogen (total collection) method gave fairly accurate digestion coefficients of forage. However, it was found to be laborious and time consuming, and it needs the use of collecting bags.

No significant difference was observed between the digestion coefficients obtained by the conventional method and by the chromogen (grab sample) method. The mean digestion coefficient estimated by grab sampling, which was 51.83 -|- 1.32 per cent, was closer to that of the conventional method (table 1) than to that of the chromogen (total collection) method. This indicates that the chromogen (grab sample) method can supplant total fecal collection. It appears that the concentration of chromogen in feces is fairly uniform throughout the day, there being no significant variability in digestion coefficients obtained by the chromogen (grab sample) method in the morning and in the afternoon.

This finding agrees with the results obtained by Soni *et al.* (1954).

*Trial II.* Digestion coefficients of Para grass, *Panicum pur*-per cent) and grab (mean, 48.81 -'- 1.18 per cent) sampling techniques did not vary significantly (table 2). As in trial I, the time of grab sampling had no effect on the concentration of the chromogen in feces; the digestion coefficient was 48.82 -|- 1.42 *purascens* Raddi, estimated by total collection (mean, 49.86 -|- 1.61 per cent for the morning sampling and 48.80 -|- 1.09 per cent for the afternoon. Digestion coefficients obtained from the different animals varied markedly both in trials I and II.

*Trial III.* No significant variation was observed among digestion coefficients obtained through the use of the different methods of estimation (table 3). The mean digestion coefficients of Alabang X, *Andropogon nodosus* (Willem.) Nash, were 50.70 -|- 1.91 per cent by the conventional method, 52.87 -|- 1.18 per cent by the total collection method, and 52.68 -|- 1.14 per cent by the grab method. The digestion coefficients among the morning grab samples did not differ from those of the afternoon grab samples. Digestion coefficients among animals, however, varied markedly.

Although only the digestibility on a dry matter basis was considered in this study, the determination of the individual digesti-

TABLE 1.—*Digestion coefficients of Alabang X,* Andropogon nodosus *(Willem.) Nash, (dry matter) measured by the conventional and chromogen methods*

| ANIMAL NO. | CONVENTIONAL METHOD | CHROMOGEN METHOD | | | |
|---|---|---|---|---|---|
| | | TOTAL COLLECTION a/ | GRAB SAMPLING b/ | | AVERAGE |
| | | | MORNING | AFTERNNON | |
| | *per cent* | | | *per cent* | |
| 1 | 55.07 | 51.88 | 51.93 | 51.93 | 51.82 |
| | | 52.55 | 52.27 | 53.69 | 51.82 |
| | | 52.78 | 52.03 | 52.78 | |
| | | 49.26 | 49.61 | 47.88 | |
| | | 52.55 | 52.92 | 52.74 | |
| 2 | 51.01 | 52.92 | 52.37 | 52.96 | 52.56 |
| | | 53.57 | 53.57 | 53.14 | |
| | | 50.92 | 52.32 | 52.27 | |
| | | 52.41 | 51.73 | 52.37 | |
| 3 | 51.96 | 52.55 | 52.41 | 51.52 | 52.37 |
| | | 52.60 | 52.60 | 52.46 | |
| | | 52.03 | 52.27 | 52.60 | |
| | | 50.20 | 49.19 | 53.48 | |
| 4 | 49.43 | 49.33 | 51.36 | 50.87 | 51.29 |
| | | 49.61 | 52.41 | 51.68 | |
| | | 53.44 | 52.96 | 52.87 | |
| 5 | 50.68 | 50.98 | 49.61 | 49.61 | |
| | | 50.92 | 50.80 | 51.83 | 51.25 |
| | | 50.92 | 50.92 | 50.87 | |
| | | 52.55 | 53.05 | 53.48 | |
| 6 | 55.06 | 50.15 | 48.81 | 59.98 | |
| | | 51.03 | 51.41 | 50.75 | 51.56 |
| | | 51.36 | 50.57 | 51.68 | |
| | | 51.93 | 53.05 | 53.44 | |
| Average | 52.20 | 51.58 | 51.58 | 51.95 | 51.79 |
| S.E. | 2.15 | 1.26 | 1,29 | 1.42 | |
| | | | | 51.83 | |
| | | | | 1.32 | |

a/ Digestion coefficients estimated from the analysis of an aliquot of the total collection.

b/ Digestion coefficients estimated from the analysis of grab samples.

*Analysis of variance*

| SV | DF | SS | MS | Computed F-value | | Prob. | .05 HSD | .01 |
|---|---|---|---|---|---|---|---|---|
| Animals | 5 | 18.4131 | 3.6826 | 20.7120 | > | .01 | .58 | .73 |
| Methods | 18 | 3.2012 | 0.1778 | 0.0745 | < | .05 | | |
| Conv. vs. chromogen | 6 | 1.0960 | 0.1827 | 0.0766 | < | .05 | | |
| Among chromogen | 12 | 2.1052 | 0.1754 | 0.0735 | < | .05 | | |
| Total vs. grab | 6 | 0.8667 | 0.1444 | 0.0605 | < | .05 | | |
| Grab (a.m. vs. p.m.) | 6 | 1.2384 | 0.2064 | 0.0865 | < | ,05 | | |
| Within methods | 54 | 128.7915 | 2.3850 | | | | | |
| Total | 77 | 150.4058 | | | | | | |

TABLE 2.—*Digestion coefficients of Para grass,* Panicum purpurascens *Raddi, (dry matter) estimated by the chromogen methods* a/

| ANIMAL NO. | CHROMOGEN METHOD | | | AVERAGE |
|---|---|---|---|---|
| | TOTAL COLLECTION b/ | GRAB SAMPLING c/ | | |
| | | Morning | Afternoon | |
| | | 47.50 | 47.79 | |
| 7 | 49.33 | 50.75 | 49.04 | 48.98 |
| | | 47.97 | 49.61 | |
| | | 50.15 | 48.65 | |
| | | 47.50 | 47.97 | |
| 8 | 49.04 | 46.00 | 46.98 | 48.02 |
| | | 47.30 | 48.81 | |
| | | 49.61 | 48.96 | |
| | | 51.98 | 47.88 | |
| 9 | 47.09 | 49.95 | 47.61 | 48.83 |
| | | 46.98 | 49.54 | |
| | | 49.61 | 48.81 | |
| | | 47.69 | 47.88 | |
| 10 | 50.57 | 49.19 | 49.68 | 48.60 |
| | | 47.79 | 47.69 | |
| | | 48.73 | 48.15 | |
| | | 46.98 | 48.32 | |
| 11 | 52.18 | 49.11 | 49.19 | 49.25 |
| | | 50.45 | 51.31 | |
| | | 48.24 | 47.50 | |
| | | 49.61 | 51.47 | |
| 12 | 50.98 | 50.27 | 50.08 | 49.92 |
| | | 48.65 | 49.04 | |
| | | 49.69 | 49.47 | |
| Average | 49.86 | 48.82 | 48.80 | 48.93 |
| S.E. | 1.61 | 1.42 | 1.09 | |
| | | | 48.81 | |
| | | | 1.18 | |

a/ The fecal samples could not be analyzed by the conventional method for moisture content because they were spoiled.

b/ Digestion coefficients estimated from the analysis of an aliquot of the total collection.

c/ Digestion coefficients estimated from the analysis of grab samples.

*Analysis of variance*

| SV | DF | SS | MS | Computed F-value | Prob. | HSD .05 | HSD .01 |
|---|---|---|---|---|---|---|---|
| Animals | 5 | 18.3063 | 3.6613 | 7.4735 | .01 | 1.09 | 1.40 |
| Methods | 12 | 5.8793 | 0.4899 | 0.2701 | .05 | | |
| Total vs grab | 6 | 5.8778 | 0.9796 | 0.5401 | .05 | | |
| Grab (a.m. vs. p.m.) | 6 | 0.0015 | 0.0002 | 0.0001 | .05 | | |
| Within methods | 36 | 75.2921 | 1.8136 | | | | |
| Total | 53 | 99.4777 | | | | | |

TABLE 3.—*Digestion coefficients of Alabang X,* Andropogon nodosus *(Willem.) Nash, (dry matter) estimated by conventional and chromogen methods*

| ANIMAL NO. | CONVENTIONAL a/ METHOD | CHROMOGEN METHOD (Per cent) | | | AVERAGE |
|---|---|---|---|---|---|
| | | TOTAL COLLECTION b/ | GRAB SAMPLING c/ Morning | Afternoon | |
| | | 55.52 | 52.55 | 52.83 | |
| 13 | 52.62 | 53.14 | 54.06 | 57.56 | 53.25 |
| | | 52.22 | 52.78 | 51.93 | |
| | | 51.93 | 52.83 | 52.32 | |
| | | 53.86 | 53.27 | 53.05 | |
| 14 | 48.79 | 51.83 | 52.08 | 53.14 | 51.94 |
| | | 52.27 | 53.61 | 48.96 | |
| | | 52.22 | 51.83 | 50.27 | |
| Average | 50.70 | 52.87 | 52.87 | 52.50 | 52.59 |
| S.E. | 1.91 | 1.18 | 0.70 | 2.35 | |
| | | | | 52.68 | |
| | | | | 1.14 | |

a/ *Digestion coefficients computed from the total dry matter intake estimated by the chromic oxide concentration and total fecal output measured by collecting bags.*

b/ *Digestion coefficients estimated from the analysis of an aliquot of the total collections.*

c/ *Digestion coefficients estimated from the analysis of grab samples.*

*Analysis of variance*

| SV | DF | SS | MS | Computed F-value | Prob. | HSD .05 | HSD .01 |
|---|---|---|---|---|---|---|---|
| Animals | 1 | 11.2597 | 11.2597 | 7.9862 | .01 | 1.11 | 1.68 |
| Methods | 6 | 8.4598 | 1.4099 | 0.4569 | .05 | | |
| Conv. vs. chromogen | 2 | 7.7395 | 3.8698 | 1.2540 | .05 | | |
| Among chromogen | 4 | 0.7203 | 0.1801 | 0.0584 | .05 | | |
| Total vs. grab | 2 | 0.1764 | 0.0882 | 0.0029 | .05 | | |
| Grab (a.m. vs. p.m.) | 2 | 0.5439 | 0.2720 | 0.0881 | .05 | | |
| Within methods | 18 | 55.5476 | 3.0860 | | | | |
| Total | 25 | 75.2671 | | | | | |

TABLE 4.—*Summary*

| METHODS | TRIAL I | TRIAL II | TRIAL III |
|---|---|---|---|
| Conventional | 52.20 -\|- 2.15 | | 50.70 -\|- 1.91 |
| Total collection | 51.83 -\|- 1.32 | 49.86 -\|- 1.61 | 52.87 -\|- 1.18 |
| Grab sampling | 51.58 -\|- 1.26 | 48.81 -\|- 1.18 | 52.68 -\|- 1.14 |

bility of organic matter such as crude protein, ether extract, nitrogen-free-extract, and crude fiber is possible. Furthermore, the grab method could be combined with the technique using chromic oxide to determine the rate of consumption of forage (dry matter) and at the same time its digestibility.

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# THE SOILS OF THE UNIVERSITY OF THE PHILIPPINES AT DILIMAN, RIZAL [1/]

MARTIN E. RAYMUNDO [2/]

WITH ONE TEXT FIGURE

The detailed soil survey of the campus of the University of the Philippines in Diliman, Rizal was conducted to evaluate the land resources of the school. This evaluation, aside from its value as a reference material, will greatly help the University in effectively pushing through its five-year development program.

## GENERAL NATURE OF THE AREA

### *Location and Extent*

The campus of the University of the Philippines in Diliman, Rizal is about 15 kilometers east northeast of Manila. It is on the back of a north-south fault escarp which gently slopes westward to the Manila Bay. The eastern boundary runs almost parallel to the face of the escarp which cradles the Balara Water Filter. The right-of-way of the National Waterworks and Sewerage Authority (NAWASA) bounds the area at the southeastern portion. The western boundary runs toward the northwest direction, the northern half is bounded by the Culiat Creek, separating the area from the site for edifices of various departments of the government and Project 6 of the Philippine Homesite and Housing Corporation, and the southern half is bounded by a portion of Marikina, Rizal. The northern boundary runs in an almost east-west direction, on the other side of which are privately owned lots and subdivisions.

The area, comprising 449 hectares, was acquired before the war but the transfer of the University from its former location at Padre Faura, Manila did not materialize until 1947. At one

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time, the area was presumably an all paddy rice field with narrow intervening shallow upland soils and exposed volcanic tuff. It was, however, altered into its present state by the scraping and damping of soils and other foreign materials when it was used by the army for installations and depots during the latter part of and after World War II, and when parts of it were converted into playgrounds and golf courses.

### *Physiography, Relief, and Drainage*

The back of the escarpment on which the campus is situated was apparently produced by a fault which is suspected to extend from the southern part of Bulacan province down south into Taal Lake in Batangas Province (Brown, 1960). The back of this escarpment is underlain by the Guadalupe tuff formation which outcrops in many spots in the campus and from which the residual soils in the area were developed. This formation is a thick sequence of well stratified andesitic tuff and tuffaceous sandstones, shales, and agglomerates found in the western and southern portion of the area at the edge of the Central Plains of Luzon (Brown, 1960). It apparently extends south into the province of Cavite. Brown believed it to be of Pleistocene deposition as evidenced by vertebrates and artifacts associated with the formation.

One feature of the beds of the Guadalupe formation is the presence of tectite, a black glassy body, usually found in Quaternary and Tertiary deposits. The Guadalupe formation is composed of two members—the Alat and the Diliman—of which the latter is dominant in the campus. The Diliman member has three recognized types which can be described as follows (Brown, 1960):

Type I.—Fairly lithified, hard, light-colored, fine grained. Andesitic in appearance with identifiable hornblende and with white specks of weathered pumice. This is most widespread in the area.

Type II.—Very fine grained consolidated volcanic dust; light-colored with concretions 1-2 centimeters in diameter formed around pumice nuclei. This type is usually overlain by leaf fossils.

Type III.—Volcanic breccia made up of pumice scoria and basalt fragments imbedded in fine grained consolidated ash and dust. Color varies from purple to light brown depending upon the dominant fragments.

In some undisturbed places within the campus, remnants of a former river bed reported by Teves and Gonzales (1950) can still be noticed. These materials apparently are the parent of the soils along the northern boundary of the campus.

The geological structure is a part of the whole structure of the Quezon City area which has a general inclination of 5 to 7° southwest. Numerous joints, strong on the east-west and weak on the northeast-southwest, contribute to the erosional features and somehow govern the general trend of drainage pattern and direction of creeks within the area.

The area varies in topography from slightly undulating to moderately rolling with only about 10 per cent having slopes greater than 40 per cent. The lowest point within the campus is in Culiat Creek with an elevation of 35 meters above sea level, and the highest point is at the ridge in the north-eastern corner with an elevation of 78 meters. The maximum difference in elevation is also located at this ridge.

There are three channels that drain the area. One rill runs from the vicinity of the library and drains into the Culiat Creek which takes care of the drainage water of the northwest portion, another in the southeastern part runs south from the women's residence area, and the third, at the northeastern section empties into the face of the escarp. The rolling condition of the area provides adequate external drainage except when dikes of paddies retard water flow. Internal drainage of the soils is generally impeded due to the heavy texture of the soil and the impermeability of the underlying tuff.

### *Climate*

The area is under type I climate as classified by Cruz and Mendoza (1952). It is characterized by two pronounced dry and wet seasons, normally dry from December to May and wet from June to November (table 1). This corresponds to the tropical Savannah climate (Goodes, 1953).

Water supply for the consumption of the University comes from the NAWASA. The farms are dependent almost entirely on rainfall for their water needs. A few small springs which make possible the culture of some plants during dry seasons exist. These

TABLE 1.—*A six-year mean monthly precipitation and temperature at Diliman* (1948-1954)

| Month | Rainfall | Temperature | Month | Rainfall | Temperature |
|---|---|---|---|---|---|
| | *Inches* | *°c* | | *Inches* | *°c* |
| January | 0.65 | 30.3 | July | 14.34 | 31.7 |
| February | 0.30 | 31.8 | August | 20.49 | 30.7 |
| March | 1.26 | 32.7 | October | 10.22 | 31.4 |
| April | 1.75 | 33.2 | November | 7.08 | 31.22 |
| May | 4.64 | 33.2 | December | 4.07 | 29.8 |
| | | | Annual | 88.25 | 31.5 |

springs serve as sources of water for home use by some families living in the vicinity of the campus. The Culiat Creek also provides water for the laundry needs of these families and, during the dry season after the harvest of rice, for small vegetable gardens found along its banks.

### *Vegetation and Agriculture*

The area may presumably have at one time been under a tropical rain forest condition, but the destruction of this forest resulted in a change of vegetation (Alicante, *et al.*, 1935). The natural vegetation which still exists in the area is the "Parang", a local term which signifies mixed grass and short growing trees and bushes. This kind of vegetation is dominant under this climate. The grasses are mostly talahib (*Saccharum spontaneum L.*) and cogon (*Imperata cylindrica* L.) while the short growing trees are generally the aroma (*Acacia farnesiana* L.) and alibang-bang (*Bauhinia acuminata* L.). This type of vegetation is abundant at the northwestern portion, particularly within the Bureau of Forestry Nursery.

Mango, santol, tamarind and cashew are the common fruit trees grown. Some areas which have been planted to ipil-ipil (*Leucena glauca* L. Benth.) can be found within the Forestry nursery. In the northeastern portion of the nursery, the ipil-ipil serve as windbreaks for bananas.

The paddies which were not altered by building or road constructions are still grown to rice during the wet season. Where water is available, either from springs or residential areas, and through irrigation during the dry season, gabi is grown. Sitao,

eggplant, and a few leafy vegetables are cultivated on paddies close to the intermittent creeks. Former paddies where the dikes have been destroyed are left idle and are used for pasture of farmers' animals whenever they are not used by the University.

### *Transportation, Markets, and Buildings*

The entire campus is crisscrossed by roads. The avenue leading to the Capitol site passes through the campus near the center towards a northeasterly direction. The main thoroughfares of the campus are asphalt paved and subsidiary roads are generally of gravel which either are newly constructed or are remnants of of roads built by the army. A number of these army-built roads presently not in use were found during the survey. Almost all points within the campus are accesible to motor vehicles, especially during the dry season.

Market facilities on the campus are inadequate. However, this is not a problem because of the proximity of the University to the city of Manila.

The U.P. campus and the surrounding areas are at present the sites of many construction jobs. Within the University, the atomic research laboratory of the Philippine Atomic Energy Commission will soon be completed, and the dilapidated army barracks which have served as student residences for years are being replaced by modern buildings. Modern and ultra-modern edifices are also being built. Near the elliptical road just a kilometer from the campus, the buildings of some government department buildings have been erected, and others will soon follow.

### *Soil Survey Methods and Definitions*

Soil surveying consists of the examination, classification and mapping of the soils in the field. The soil surveyor walks over the area at intervals of not more than 100 meters apart and bores with an auger or digs holes with a spade. Each boring or hole shows that the soil consists of several distinct layers known as horizons. Collectively, the series of horizons or layers is called a profile. Each layer is studied for possible effects on plant growth.

The color is noted according to the Munsell color notations. The dark color of the top soil may be associated with organic

matter, and spots and streaks of gray, yellow, brown, and other mottles are indications of poor drainage conditions, especially if they occur very close to the surface. Texture (sand, silt and clay contents) is determined by the feel of the soil and later checked through mechanical analysis in the laboratory. Texture determines the ability of the soil to retain moisture, hold nutrients and resist leaching and erosion, and the suitability of the soil to cultivation and drainage. Structure, or the way the soil particles are aggregated, and the size of pores or open spaces between the soil granules, indicate the ease by which plant roots and water can penetrate. Consistency, or the tendency of the soil to crumble or stick together, indicates the difficulty of maintaining porous soil after cultivaton. The kind of rocks or parent material from which the soils have been developed affects the quantity and kind of nutrients that the soils naturally possess. Simple chemical tests using indicator dyes show the acidity of the soils. Depth to the bedrock or parent material is determined. The quantity of gravels or stones that may interfere with cultivation and other external features are observed.

On the basis of these characteristics, soil areas that are much alike in kind, thickness, and arrangement of their layers are mapped as one soil type, such as Guadalupe clay loam. A type may be separated into two or more phases, as Culiat clay normal paddy phase and Culiat clay upland phase, based on land uses; or Diliman clay normal phase and Diliman clay shallow phase. Whenever very small areas of soils are so intricately mixed that they cannot be shown separately, and when the less dominant becomes an inclusion of the dominant soil or occur in nearly the same extent, these soils are named in mixed groups. The soil type or the soil phase is used as the basic mapping unit for specific management needs. For example, the shallow phase of the Guadalupe clay could not be cultivated because of the presence of tuff outcrops which hinder cultivation.

## *Soils*

The soils of the University of the Philippines at Diliman, Rizal were formed under an environment of warm tropical climate with alternate dry and wet seasons, and with mixed grass and short tree vegetations. The parent material of the soils are essentially Gua-

dalupe tuff which is andesitic in composition. The soils are heavy textured and are medium acid in reaction. Their color generally ranges from very dark brown to black except for the Novaliches series.

Although the soils have relatively uniform general properties, they exhibit a rather wide variation due to differences in physiographic position, drainage, and cultural practices. For agricultural purposes, the types of soils can be considered from poor to fair.

The soils of U.P. Diliman were mapped as Novaliches clay loam adobe phase in the reconnaissance soil survey of the province of Rizal (Alicante, *et al.*, 1935). More detailed studies showed that soils which approach the properties of the Novaliches series occupy a very minor portion of the area. Most of the soils are similar to if not the same as the Guadalupe series. A map showing the soils of the U.P. in Diliman is presented in this report.

### *Soil Series and their Relations*

A soil series is a group of soils having similar genetic horizons except for the texture of the surface soils, similar arrangement of horizons in the profile, and similar parent material. The soils are classified into five series according to drainage, parent material, age, and related profile features. The Guadalupe series and the Novaliches series are established series, while the others are tentative names of series which are proposed for the soils that have been studied and characterized in the process of this survey. The soil series are grouped into the following for identification: (1) The red soils of the upland, (2) the dark-colored soils of the upland, and (3) the soils of the paddy. The soils classified and mapped are the Guadalupe series, Culiat series, and Diliman series.

### *The Upland Soils*

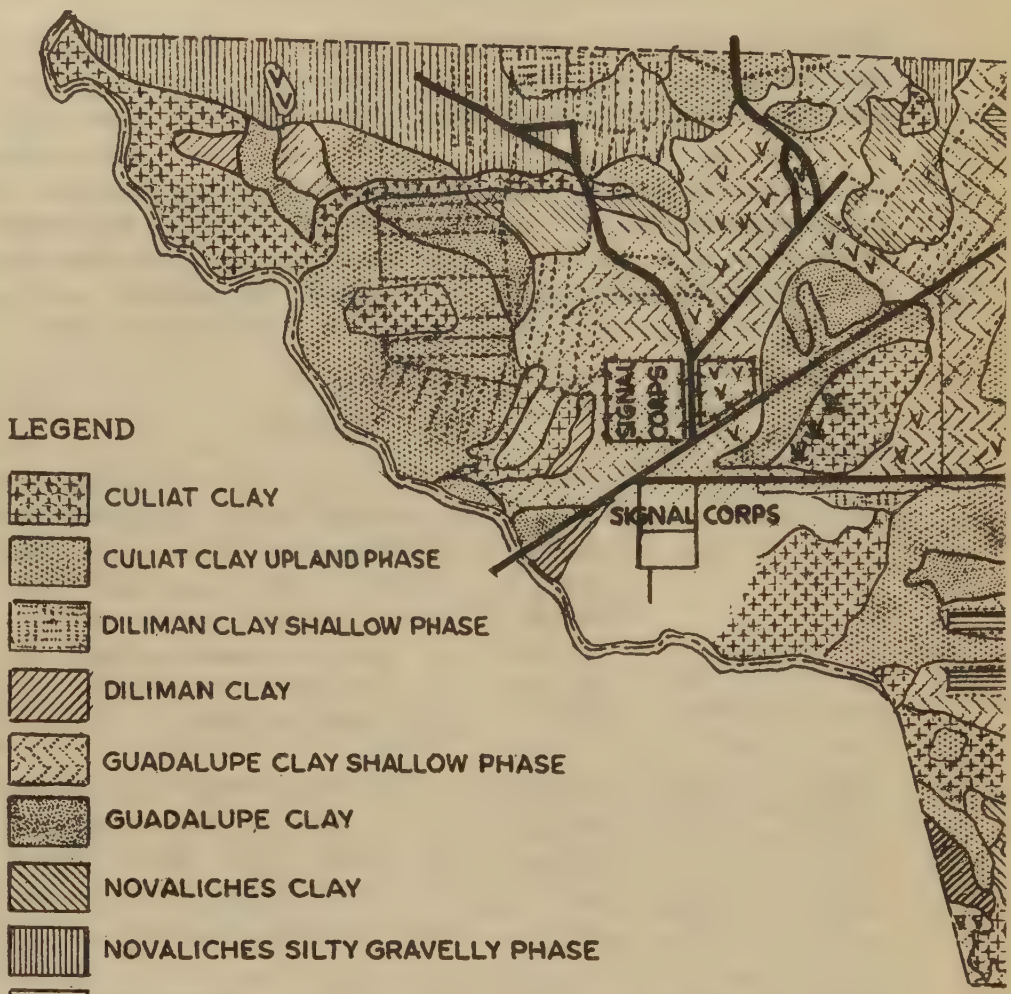
*The Novaliches series*—Novaliches soils are reddish brown on the surface and red, yellowish red to dark red in the lower horizons. These are well drained soils normally found on convex moderate slopes. The surface and the subsoils are friable. Spherical iron concretions are common in the subsoil and black streaks which effervesce violently with hydrogen peroxide coat the aggregates. They are underlain by yellowish tuff which are highly weathered.

This soil when not eroded varies in depth from 80 centimeters to 200 centimeters. Fruit trees are common in and bamboo was observed to cover a relatively wide portion of this soil area.

There are two types of this series. One is a gravelly silty clay loam which dominates the ridge that runs almost parallel to the northern boundary of the campus, and the other is a clay found in the areas close to Barrio Balara and Cruz na Ligas along the southeastern and the southwestern borders of the campus.

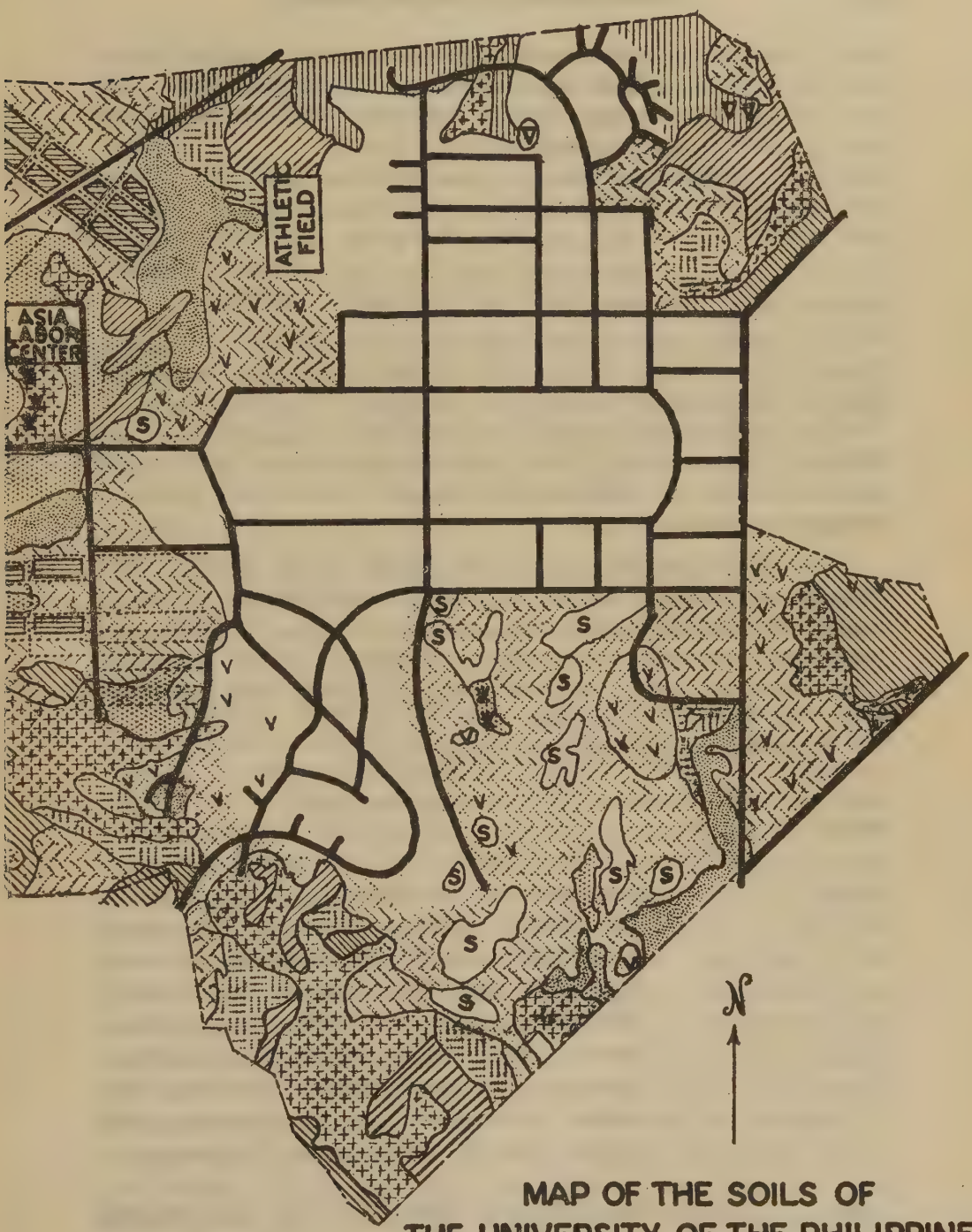
A profile in an uncultivated area was described as follows:

| *Horizon* | *inches Depth* | *Morphology* |
|---|---|---|
| $A_1$ | 0-8 | Reddish brown (5 YR 4/3 to 4/4 ) clay or clay. Very coarse angular blocky structure that breaks into fine granular or fine subangular sticky and slightly plastic when wet. Few blocks. Friable when moist, sticky and plastic when wet. Roots of grasses profusely distributed. pH 5.2, mild effervescence with $H_2O_2$. Gradual lower boundary. |
| $B_{21}$ | 8-22 | Dark red (2.5 YR 3/6) gravelly clay. Coarse subangular blocky breaking to fine granules. Compact but friable when moist, slightly roots, very weak effervescence with peroxide, pH 5.7. Boundary clear and smooth. |
| $B_{22}$ | 22-40 | Red (2.5 YR 4/8) clay. Coarse subangular blocky breaking into fine and medium weak granules. Moderately compact but friable when moist. Sticky and plastic when wet. Faint brown (7.5 YR 5/4) spots which increase with depth. Very weak effervescence with peroxide, pH 5.5. Diffuse smooth lower boundary. |
| $B_3$ | 40-48 | Red (2.5 YR 4/8) clay with common brown (7.5 YR 4/8) mottles. Black material found separate or as partial coats of agregates effer- |




LEGEND

- CULIAT CLAY
- CULIAT CLAY UPLAND PHASE
- DILIMAN CLAY SHALLOW PHASE
- DILIMAN CLAY
- GUADALUPE CLAY SHALLOW PHASE
- GUADALUPE CLAY
- NOVALICHES CLAY
- NOVALICHES SILTY GRAVELLY PHASE
- S DUMPED SOIL
- V V EXPOSED TUFF
- ∇ ∇ BOULDERS ON SURFACE
- ——— SOIL BOUNDARY
- ——— CAMPUS BOUNDARY
- ..... OLD GRAVEL ROADS
- W W WET SPOTS
- CONCRETE PAVEMENTS
- ━━━ EXISTING TRAFFIC




MAP OF THE SOILS OF
THE UNIVERSITY OF THE PHILIPPINES
AT DILIMAN, RIZAL

SCALE 1:25,000

vesce violently with peroxide. Slightly sticky and slightly plastic. Yellowish brown tuff very common. pH 5.6. Clear smotoh lower boundary.

$C_1$ 48-58 and below. Yellowish brown (10 YR 5/3 to 5/4) clay loam with common black streaks on surface of fissures of the tuff. Violently effervescent with peroxide. Fragile compact, non-sticky and non-plastic. pH 5.6.

The profile exhibits the morphology of a typical Low Humic Latosol (Cline, 1954). These soils are also dominant in the areas close to the boundary between the provinces of Rizal and Bulacan.

The gravelly phase of this series was found along the northern boundary of the campus. The profile is characterized by a considerable amount of water-worked gravels. Genetically, however, these two soils are related.

The Novaliches silty clay loam, gravelly phase, contains gravels and stones which obstruct digging. Some limestone fragments can be found on the surface but are suggestive more of artificially transported material rather than a component of the materials from which the soils developed. This is hallower and lighter in color than the Novaliches clay.

A profile was described as follows:

| *Horizon* | *Depth inches* | *Morphology* |
|---|---|---|
| $A_1$ | 0.5 | Dark reddish brown (5 YR 3/2) clay with water worked gravel and stones imbedded about 10-15% of the soil mass some are limestone fragments apparently deposited artificially. Moderately strong subangular blocky structures. Hard, plastic and sticky. Some fine gravels or concretion occur in pellet form. Few roots. Soil mass effervescing moderately with H2O2. pH 6.4. Clear smooth boundary. |
| $B_{21}$ | 5-11 | Dark yellowish brown (10 YR 4/4) gravelly |

| | | |
|---|---|---|
| | | dense clay. Water worked Andesitic gravels 2 inches compose 20-25% of the soil mass Very few root. Prominent high contrast black and reddish brown (5 YR 3/3) mottles. Black concretions and soil mass effervesce violently with $H_2O_2$. Very dark; very sticky and highly plastic. pH 6.0. Gradual smooth boundary. |
| $B_{22}$ | 11-16 | Brown to yellowish brown (10 YR 5/3 to 5/4) gravelly clay with very fine white particles from decomposed gravels. Brown mottles common; fine black concretion (1-2 mm) effervesce with $H_2O_2$. massive structure breaks to fine and medium subangular blocks. Hard; very sticky and highly plastic. pH 5.8. Boundary clear and smooth. |
| $B_{23}$ | 16-26 | Similar to above but more friable and on-gravelly. pH 5.8. |
| C | 26-32 | Gray brown (10 YR 5/2) sandy clay with gravels almost 30%. Hard, sticky and plastic. pH 6.0. |

*Guadalupe series.*—The areas under this soil series have been disturbed and areas with the least modifications are rather scarce. This soil is generally black when moist and dark gray when dry. Some reddish streaks and mottles were observed. This soil type was found to be associated with undulating to moderately sloping areas and underlain by a hard tuffaceous stratified rock apparently belonging to the first type of the Diliman member of the Guadalupe formation. This is a normally shallow soil and only in very few spots on the campus can it be cultivated. The separation of the normal phase and the shallow phase was primarily determined from the possibility of the area for cultivation. The shallow phase includes areas which are spotted with tuff outcrops making cultivation impossible. Some of the deep soils which have been dumped were included in the deep phase. The golf course, the western portion of the University High School compound, the areas east of the College of Veterinary Medicine compound and some extensive areas around the site for the atomic reactor were mapped under this soil series.

A profile close to a cultivated area with about 8 to 12 per cent slope and still under cogon and talahib vegetation was described. Some variants of this soil show mottled subsoils.

| *Horizon* | *Depth inches* | *Morphology* |
|---|---|---|
| 11 | 0-13 | Dark brown (7.5 YR 3/2) friable fine granular clay loam. Sticky and plastic when moist. Roots profusely distributed. Slightly effervescent to peroxide. pH 5.7. Gradual smooth boundary. |
| $A_{12}$ | 13-16 | Brown to yellowish brown (10 YR 5/4 to 5/5) with light brownish gray gravelly sand seemingly weathered from the underlying tuff. |

This soil represents a lithosolic stage of the Grumusol, otherwise known as self-swallowing or self-mulching clay. This differs from the typical Guadalupe series by its lighter color. Similar soils have been found to respond to phosphorus application.

### *The Paddy Soils*

Paddy soils have not been separated from the associated upland soils in previous studies made in different parts of the Philippines. The writer believes that for purposes of detailed classification, the soils of the paddy, especially in areas where the paddies have existed for decades and centuries, have developed properties which warrant a full separation from the upland soils from which these paddy soils may have developed. For this reason, the soils of the paddies were classified and mapped separately, and new names were introduced subject to verification as to whether or not they fit into the characteristics of already established soils series.

Two main series are proposed: a) deep soils with gleyed lower subsoil and b) soils which are shallow or moderately deep but not deep enough to produce the characteristic gley of the paddy soils and possess characteristics that differentiate them from the upland soils.

1. *Culiat Clay* — This soil is characterized by a deep profile with a dark brown to dark reddish brown surface, and has variable intensities of iron mottles and few black manganese concretions. Below the cultivated layer, it possesses a compact concretionary

horizon, which may be 2 to 12 inches in thickness. Below this compact concretionary layer is a gleyed horizon which normally has some manganese concretions. This layer has a doughy character and extends from 40 to 60 inches in depth. Highly weathered tuff is the parent material of this soil. The weathered material may attain a thickness of 4 to 10 inches. Below this is a gray consolidated tuff.

Some areas of this soil type have been reconverted to upland fields by removing the dikes but the normal paddy soil character still remains. These portions are mapped as Culiat Clay upland phase. Extensive areas of the paddy and upland phase of this series are found along the western boundary of the campus. The sites for the proposed University General Hospital, Institute of Hygiene and the area west of the Signal Corps and south of the Bureau of Forestry Nursery are primarily of this soil type.

A profile typical of this soil was described on a paddy at the middle of a 200 meter slope with a gradient of 15 per cent.

| *Horizon* | *Depth inches* | *Morphology* |
|---|---|---|
| $A_p$ | 0-4 | (sometimes 5 inches) Dark gray (5 YR 4/1) with striking yellowish red (5 YR 4/8) mottles associated with roots and root channels. Clay, structureless (massive) breaking into very coarse blocks with non-shiny surface. Hard, very sticky and very plastic, firm. Profuse fine roots. Many fine (.5 mm-2mm) red concretions and medium to coarse black concretion which effervesce violently with peroxide. pH 5.4. Boundary abrupt. |
| $B_{2cn}$ | 4-19 | (sometimes only 12 or 15) Very dark gray brown (10 YR 3/2) with black coarse. Concretions of iron and manganese. Clay, structureless (massive) breaking into 5 to 10 cm. dull colored clods. Roots few. Sticky and plastic, very firm. pH 5.4. Abrupt regular boundary. |
| $B_{2g}$ | 19-27 | (sometimes only 12 to 20) Pale olive to olive |

| | | |
|---|---|---|
| | | gray (5 Y 6/2-6/3) Clay, structureless, very sticky and very plastic. Very few concretions and moderately effervescent with peroxide. ph. 5.4. Boundary clear and smooth. |
| $B_{3g}$ | 27-39 | (sometimes 56) Same as above in main properties but with plenty of brownish yellow (10 YR 6/6-6/8) broken and highly weathered volcanic tuff. ph. 5.2. Boundary gradual and smooth. |

2. *Diliman clay* — This soil type is characterized by a dark reddish brown or dark brown surface horizon with common iron and manganese concretions. The subsoil is dark reddish brown, compact and concretionary and differs from the Culiat series by the absence of gleyed subsoil. The soil depth is less than 12 inches in the shallow phase and may go as deep as 24 to 36 inches in the normal soil. Immediately under the subsoil is the consolidated gray Guadalupe tuff. This soil series is composed of three phases, the shallow and normal phase of the paddy and the upland phase where the dikes have been removed to revert the area to upland conditions.

Having this soil are the areas north of the Forestry Nursery, north of the University Avenue, east of the Signal Corps, east of the Asia Labor Center, north of the athletic field, south and west of the faculty housing area, and the lowland rice fields in the northeastern section adjacent to the Balara Compounds.

A profile typical of this soil was described on a paddy at the middle of a 200-meter slope with a gradient of 15 per cent.

| *Horizon* | *Depth inches* | *Morphology* |
|---|---|---|
| $A_p$ | 0.4 | (Sometimes 5 inches) Dark gray (5 YR 4/1) with striking yellowish red (5 YR 4/8) mottles associated with roots and root channels. Clay structureless (massive) breaking into very coarse blocks with non-shiny surface. Hard, fine (.5 mm-2 mm) red concretions and medium to coarse black concretion which effervesce violently with peroxide. pH 5.4 Boundary abrupt. |

$B_{2cn}$ 4-9 (sometimes only 12 or 15 inches) Very dark gray brown (10 YR 3/2) with black coarse concretions of iron and manganese. Clay, structureless (massive) breaking into 5 to 10 cm. dull colored clods. Roots few. Sticky and plastic, very firm. pH 5.4. Abrupt regular boundary.

$B_{2g}$ 19-27 (sometimes only 12 or 20) Pale olive to olive gray ( 5 Y 6/2-6/3) Clay, structureless, very sticky and very plastic. Very few concretions and moderately effervescent with peroxide. pH 5.4. Boundary clear and smooth.

$B_{3g}$ 27-39 (sometimes 56) Same as above in main properties but with plenty of brownish yellow (10 YR 6/6 to 6/8) broken and highly weathered volcanic tuff. pH 5.2. Boundary gradual and smooth.

*Land-use and Management Recommendations*

The use of land in the U.P. Diliman campus for agricultural purposes is rapidly diminishing and within a few years, plantings will be confned to landscape improvement and the development of recreational facilities. Consequently, recommendations will be directed to these uses.

For the deep soils which by nature are poorly drained, artificial drainage--preferably open drainage canals—will be needed if trees and turfs which are sensitive to poor drainage are to be estabblished. The heavy texture of this soil makes subsurface drainage or tile drains ineffective due to poor soil permeability especially in the lower horizons.

The low spots in the areas covered by this soil are potential sites for artificial ponds which may be used for water storage, fish ponds, or ponds for recreation. The area east of the U.P. High School, the low spots close to the golf course along the south-

eastern boundary and at the southern tip, and the depression at the northeast section are favored for this purpose by the narrow gaps on the outlets where dams could be constructed and maintained at minimum cost. Considering the long dry season of the area, however, additional water to maintain the pond during the said period must be considered.

When left uncultivated, the soils in these paddies are apparently able to support the lush growth of tall growing grasses like talahib and cogon which when not kept under control will be a hazard to the planted vegetative cover due to competition for nutrients and water. These grasses are potential sources of fire during dry seasons. They could also retard the growth of the plants.

The shallower paddy soil which is normally ungleyed can be easily reverted to upland conditions and readily adapted to ornamental shrubs, trees, and grasses. The drainage of the soil can be turned to normal by merely removing the dikes and by plowing deeply to destroy the impermeable layer immediately below the puddled zone. Timely preparation must be taken into consideration if the soil is to have a desirable physical condition. The land could best be broken as soon as the soil, after a few hard rains at the start of the rainy season, is dry enough to be touched by implements without clodding.

If lawn grasses are to be planted, it will be wise not to do so when the soil is too wet. If very shallow places of the paddies are to be planted to trees, the holes must be at least one cubic meter in size, and should be refilled with soils high in organic matter or manure—soil mixture before the seedlings are set. This holds true not only for the shallow paddy soils but also for shallow upland soils and exposed tuff areas where the trees are intended to be grown.

Most of the soils in the area will be suitable to turf cover unless they are water-logged during the wet season. If the soil is more than a foot in thickness, additional soil must be dumped in order to have a good stand of the sod. To maintain the sod during the dry season, overhead irrigation is a necessity.

Planted trees will also require frequent to occasional watering especially during the first few dry seasons. Where planting spots hit the hard exposed tuff, it has been observed in areas similar to

this that a stick of dynamite to blast a hole proves more ecoonmical than man labor. Refills must be similar to any holes dug partly or wholly from the tuff.

### *Some Engineering Properties of the Soils and Bedrocks*

The soils in the area are very poor for engineering uses such as road fills, underdrainage, and foundation materials. The gravelly soils will be fair for these purposes. The underlying tuff on the other hand will make an ideal foundation and materials scraped from this tuff will be a good source of road fills and pavements. This tuff will considerably increase expenses incurred in excavations for pipelines and canals, and in grading for beautification and constructions.

### *Mechanical Analysis and some Chemical Properties of the Soils*

The mechanical analysis of the soils showing the amount of sand, silt, and clay are shown in table 2. With few variations, the sand particles increase with the depth of the soil. The lack of a definite trend of the particle size distribution in the Novaliches silty clay loam gravelly phase apparently concurs with the possibility that the soil was formed from materials deposited on the river bed wherein there was poor sorting of the materials. Otherwise, all of the soils in the campus have been derived from the underlying tuff. The clay particles in the dark colored soils seem to be of the expanding type (2:1), but the red soils may be dominated by the sesquioxide clays.

One noticeable feature of Culiat clay is the very high concentration of clay immediately below the plowed layer and the very low amount of sand and silt particles. In the Diliman clay which is also a paddy soil, the clay content is higher in the surface. The latter may be considered normal for paddy soils since the clay is suspended during puddling and the coarser particles tend to be deposited at the lower portion much faster. The condition of high clay concentration may be an exception rather than a rule, but it is noteworthy that attention has to be diverted to the properties of the paddy soils which are not yet detailedly explored in spite of the fact that a great percentage of farm lands in the Philippines are used for paddy rice production.

TABLE 2.—*Mechanical analysis of five soil profile from U.P. Diliman Campus*

| DEPTH INCHES | HORIZON | SAND (Per cent) | SILT (Per cent) | CLAY (Per cent) |
|---|---|---|---|---|
| | | Guadalupe clay loam | | |
| 0-13 | $A_1$ | 68.1 | 14.1 | 17.8 |
| 13-16 | A/C | 33.0 | 26.7 | 40.6 |
| 16-28 | C | 24.7 | 35.7 | 39.6 |
| | | Novaliches clay | | |
| 0-8 | $A_1$ | 25.7 | 27.0 | 47.1 |
| 8-22 | $B_{21}$ | 25.7 | 25.3 | 49.0 |
| 22-40 | $B_{22}$ | 24.7 | 19.3 | 56.0 |
| 40-48 | $B_3$ | 24.8 | 19.5 | 55.7 |
| 48-58 | $C_1$ | 32.2 | 26.2 | 41.6 |
| | | Novaliches silty clay loam gravelly phase | | |
| 0-5 | $A_1$ | 49.9 | 20.9 | 29.2 |
| 5-11 | B21 | 38.8 | 18.5 | 43.4 |
| 5-11 | $B_{21}$ | 38.8 | 18.5 | 43.4 |
| 11-16 | $B_{22}$ | 29.7 | 28.4 | 24.6 |
| 16-28 | $B_{23}$ | 44.6 | 28.4 | 27.0 |
| 28-32 | $C_1$ | 46.0 | 29.4 | 24.6 |
| | | Diliman clay | | |
| 0-4 | $A_p$ | 21.7 | 26.3 | 52.0 |
| 4-10 | $B_{2cn}$ | 27.2 | 24.2 | 48.6 |
| 10-17 | $B_{2gcn}$ | 29.2 | 21.7 | 37.1 |
| 17-24 | $B_3$ | 34.4 | 22.6 | 43.0 |
| | | Culiat clay | | |
| 0-4 | $A_p$ | 16.4 | 22.1 | 61.5 |
| 4-19 | $B_{22t}$ | 4.5 | 6.1 | 89.4 |
| 19-27 | $B_{22}G$ | 19.0 | 13.1 | 67.9 |
| 27-39 | $B_3G$ | 14.4 | 18.3 | 67.3 |
| 39-56 | $C_1$ | 9.9 | 24.0 | 66.1 |

The chemical analyses of representative profiles are shown in table 3. The soils are very acid to moderately acidic. The pH of the Novaliches clay is critical for most plants. Lime may be necessary in order to make use of this soil for crop production. The organic matter level of the soils may be considered adequate for common field soils but the Novaliches clay can profit more from

TABLE 3.—*Chemical analysis of representative upland and paddy soil profile from U.P. Diliman Campus*

| DEPTH (INCHES) | HORIZON | PH | O.M. | P | K | CA | MG | CEC |
|---|---|---|---|---|---|---|---|---|
| | | % | PPM | | | M.E./100 G. | | |
| | | | | Culiat clay | | | | |
| 0-4 | $A_p$ | 5.25 | 2.74 | 4.06 | 0.22 | 16.32 | 7.57 | 32.8 |
| 4-19 | $B_{21m}$ | 5.7 | 2.13 | 3.44 | 0.16 | 16.96 | 6.84 | 31.2 |
| 19-27 | $B_{22}$ | 5.5 | 0.76 | 1.88 | 0.08 | 20.52 | 10.40 | 40.4 |
| 27-39 | $B_3$ | 5.6 | 0.14 | 2.82 | 0.11 | 24.04 | 12.70 | 41.6 |
| 39-56 | $C_1$ | 5.6 | 0.51 | 4.06 | 0.08 | 22.68 | 11.38 | 39.2 |
| | | | | Novaliches clay | | | | |
| 0-8 | $A_1$ | 4.8 | 1.22 | 1.88 | 0.06 | 8.92 | 6.84 | 24.8 |
| 8-22 | $B_{21}$ | 4.75 | 1.59 | 6.26 | 0.05 | 5.72 | 4.54 | 21.6 |
| 22-40 | $B_{22}$ | 4.8 | 0.55 | 1.26 | 0.05 | 9.76 | 6.84 | 26.0 |
| 40-48 | $B_3$ | 4.8 | 0.36 | 1.88 | 0.06 | 14.80 | 11.58 | 24.0 |
| 48-58 | C | 5.05 | 0.08 | 5.62 | 0.06 | 19.16 | 15.07 | 48.8 |
| | | | | Guadalupe clay loam | | | | |
| 0-13 | $A_1$ | 5.7 | 3.17 | 18.76 | 0.28 | 19.84 | 8.55 | 35.2 |
| 13-16 | A/C | 5.55 | 2.02 | 5.62 | 0.24 | 20.52 | 8.36 | 33.2 |
| 16-28 -\|- | C | 5.85 | 0.29 | 19.61 | 0.24 | 26.88 | 11.88 | 40.8 |

organic matter maintaining practices. Calcium and magnesium are by most standards adequate but phosphorus and potassium contents will be considered low under common standards. The need for these two latter nutrients were also apparent in the vegetation during the field survey but experimentation of trials must be necessary to verify suspected deficiency of these two nutrients.

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# NITRIFICATION IN COCONUT SOILS [1/]

CONCEPCION L. VALERA, S. N. TILO
and ERLINDA N. SEMINIANO [2/]

**The rate of nitrification in six coconut soils from cadang-cadang infected plantations in the Bicol region was estimated by incubating representative soil samples amended with ammonium sulfate and lime for 28 days at 30°C. Nitrate production was high in five soils supplied with 200 ppm. $NH_4$—N despite their acidic reaction. The rates of nitrification, however, varied significantly. Mineralization of organic nitrogen occurred in all soils as indicated by their mineral N contents which exceeded the amount initially present plus the $NH_4$—N added. In the unlimed soils, the pH dropped to as low as 4.4 after 28 days. The application of 2.5 tons of $CaCO_3$ per hectare raised the pH of the soils by 0.4 to 1.1 units.**

**The data suggest that the soils used in this study support an active nitrifying microflora which is apparently adapted to low pH.**

The present status of the "cadang-cadang" disease of coconut trees in the Bicol region is appalling and yet a correct diagnosis of the disease has not been established. To prolong the productive life of affected trees, good soil management practices must be employed. The use of fertilizers to increase coconut yield has been successfully attained in Laguna (Felizardo and Galvez, 1960).

Most, if not all, of the nitrogenous fertilizers used in this country are in the ammonium form. But ammonium nitrogen added to the soil must first be nitrified for nitrate is the principal form of nitrogen absorbed by plants. In the absence of added available nitrogen, plants depend on the mineralization of organic nitrogen. The amount of organic nitrogen mineralized in a fixed length of time provides an estimate of the availability of nitrogen. The present work was conducted to assess the nitrate-supplying power of six coconut soils in the Bicol region.

## MATERIALS AND METHODS

The soils were collected from coconut plantations seriously af-

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fected with cadang-cadang in the provinces of Albay, Camarines Norte, Camarines Sur, and Sorsogon. The description and some properties of these soils are presented in table 1. Five trees were selected at random in each plantation. Ten cores of the 0

TABLE 1.—*Description and properties of the soils*

| SAMPLE No. | SOIL TYPE | LOCATION | pH | ORGANIC MATTER | CATION EXCHANGE CAPACITY |
|---|---|---|---|---|---|
| | | | | *per cent* | *m.e.1/00 grams* |
| CN-13 | Beach sand | Paracale, Camarines Norte | 5.0 | 3.0 | 5.82 |
| CS-13 | Beach sand | Pasacao, Camarines Sur | 5.8 | 2.1 | 11.58 |
| CS-33 | San Manuel loamy sand | Sagnay, Camarines Sur | 5.7 | 7.9 | 23.94 |
| AL-13 | Guinobatan loamy sand | Guinobatan, Albay | 5.4 | 4.1 | 9.20 |
| AL-23 | Mayon loamy coarse sand | Tabaco, Albay | 5.6 | 2.7 | 8.26 |
| SOR-33 | Irosin loamy fine sand | Irosin, Sorsogon | 5.3 | 5.2 | 11.36 |

to 10-inch layer around two meters from the base of each tree were taken with the use of a sampling tube. The core samples collected under each tree were composited and stored in black polyethylene bags which were transported to the Department of Soils. Each composite sample was thoroughly mixed and passed through a 2-mm. sieve. Twenty-five gram aliquots of the fresh soil were weighed in petri dishes and given the following treatments: a) no amendment or control, b) 200 ppm N as ammonium sulfate and c) 200 ppm. N as ammonium sulfate plus lime. The moisture contenttent of the soils was brought up to 20 per cent and maintained at this level throughout the incubation period. The treated soils were incubated at about 30°C. Samples were taken at intervals of 0, 7, 14, and 28 days for pH, ammonium, nitrite and nitrate analyses.

The pH of the soils was determined with the glass and calomel electrodes using a 1:1 soil-water ratio. For the analyses of ammonia, nitrite and nitrate, a 10 g.—aliquot of the incubated soil

was leached with 100 ml. of Morgan's solution [3/] in a Buchner funnel. At the same time 5 grams of the same soil were placed in an aluminum weighing can for moisture determination. The leachate was transferred into a 100-ml. volumetric flask, made up to volume with the extracting solution and mixed well. Ammonia was analyzed using the Nessler's reagent (Peech, *et al.*, 1947). Nitrite was determined according to the method of Prince (1945) using sulfanilic acid and alpha-naphtylamine reagents. The brucine method (Colowick and Kaplan, 1957) was used in the analysis of nitrate.

## RESULTS AND DISCUSSION

The changes in nitrate and ammonium nitrogen during incubation are shown in tables 2 and 3, respectively. No appreciable amount of nitrite was present in any of the soils at all sampling periods. Nitrite accumulations in acid soils are rarely observed because of the unstable nature of nitrite-nitrogen under acidic conditions (Tyler and Broadbent, 1960).

Nitrate production was high in five soils supplied with ammonium-nitrogen despite their acid reaction. The rates of nitrification, however, varied significantly. Ammonium oxidation proceeded at much faster rates when the soils were limed. Chandra and Bollen (1960) have also demonstrated much higher nitrifying capacity of soils on addition of $CaCO_3$. At the end of 28 days over 200 ppm N was recovered as nitrate in all limed soils with the exception of AL-13 (Guinobatan loamy sand) in which only 77 per cent of the added ammonuim nitrogen appeared as nitrate. The amount of $NH_4$—N was still high, 112.7 ppm at the end of the incubation period. Nitrite in this soil was practically nil at all sampling periods suggesting a slower activity of the *Nitrosomonas* population which converts ammonium to nitrite than that of the *Nitrobacter* group which oxidizes nitrite to nitrate. The relatively slower rate of nitrification in this particular soil type was more marked in the unlimed treatment as shown by the small increases in nitrate content with time compared to the other unlimed soils.

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3/ Prepared by dissolving 100 g. of sodium acetate in 500 ml. of distilled water. Thirty ml. of 99.5% acetic acid were added and the volume made up to 1 liter.

TABLE 2.—*Nitrate production in Bicol coconut soils*

| SAMPLE NO. | TREATMENT a/ | INCUBATION PERIOD IN DAYS | | | |
|---|---|---|---|---|---|
| | | 0 | 7 | 14 | 28 |
| | | | *ppm N* | | |
| CN-13 | Control | 5.1 | 5.8 | 0.6 | 14.4 |
| | 200 ppm N | 11.1 | 12.6 | 58.9 | 102.2 |
| | 200 ppm N -\|- lime | | 20.6 | 58.3 | 200.4 |
| CS-13 | Control | 2.9 | 8.9 | 9.6 | 47.7 |
| | 200 ppm N | 1.0 | 18.5 | 38.2 | 184.5 |
| | 200 ppm N -\|- lime | | 67.5 | 90.7 | 298.6 |
| CS-33 | Control | 7.1 | 26.6 | 14.2 | 64.8 |
| | 200 ppm N | 4.3 | 20.0 | 108.8 | 269.0 |
| | 200 ppm N -\|- lime | | 104.5 | 180.3 | 317.6 |
| AL-13 | Control | 6.8 | 5.5 | 8.2 | 11.8 |
| | 200 ppm N | 9.3 | 9.7 | 20.3 | 67.6 |
| | 200 ppm N -\|- lime | | 19.3 | 53.8 | 155.3 |
| AL-23 | Control | 3.2 | 4.9 | 7.9 | 9.1 |
| | 200 ppm N | 3.4 | 9.8 | 70.7 | 181.9 |
| | 200 ppm N -\|-lime | | 46.0 | 108.0 | 202.6 |
| SOR-33 | Control | 1.7 | 22.2 | 18.8 | 26.1 |
| | 200 ppm N | 1.9 | 47.9 | 155.6 | 219.6 |
| | 200 ppm N -\|- lime | | 68.5 | 105. | 200.0 |

a/ N was supplied in the form of $(NH_4)_2SO_4$ and lime as $CaCO_3$ at the rate of 2.5 tons to a hectare except CN-13 which received lime as CaO at the rate of 5.0 tons per hectare.

The sum of $NH_4$—N and $NO_3$—N in all soils treated with $(NH_4)_2SO_4$ (limed or unlimed) exceeded 200 ppm. plus the amount initially present indicating that mineralization of organic nitrogen had taken place. The soils had high organic matter contents ranging from 2.1 to 7.9 per cent (table 1). San Manuel loamy sand (CS-33) had the highest organic matter content and also contained the highest nitrate levels in the final sampling of both control and amended soils. It was noted, however, that in all cases the $NH_4$—N + $NO_3$—N in the limed soils was lower than those treated with $(NH_4)_2SO_4$ alone. The differences may have been due to nitrogen immobilization or loss through denitrifica-

TABLE 3.—*Ammonium-nitrogen of Bicol coconut soils during incubation*

| SAMPLE NO. | TREATMENT | INCUBATION PERIOD IN DAYS | | | |
|---|---|---|---|---|---|
| | | 0 | 7 | 14 | 28 |
| CN-13 | Control | 6.9 | 13.5 | 9.9 | 9.8 |
| | 200 ppm N | 218.3 | 264.0 | 232.5 | 128.2 |
| | 200 ppm N -|- lime | | 209.2 | 126.0 | 8.7 |
| CS-13 | Control | 11.0 | 25.2 | 10.1 | 12.4 |
| | | 251.5 | 34.70 | 259.3 | 194.5 |
| | 200 ppm N -|- lime | | 316.5 | 97.6 | 8.4 |
| CS-33 | Control | 8.6 | 25.9 | 18.6 | 14.9 |
| | 200 ppm N | 237.1 | 322.5 | 259.0 | 77.2 |
| | 200 ppm N -|- lime | | 262.8 | 152.3 | 15.5 |
| AL-13 | Control | 5.0 | 20.1 | 8.3 | 12.1 |
| | 200 ppm N | 225.0 | 296.2 | 281.0 | 266.4 |
| | 200 ppm N -|- lime | | 267.8 | 199.0 | 112.7 |
| AL-23 | Control | 3.5 | 24.3 | 24.4 | 10.4 |
| | 200 ppm N | 226.6 | 320.9 | 290.5 | 184.9 |
| | 200 ppm N -|- lime | | 224.7 | 174.9 | 8.5 |
| SOR-33 | Control | 5.5 | 19.9 | 13.3 | 10.2 |
| | 200 ppm N | 233.9 | 267.2 | 258.8 | 74.2 |
| | 200 ppm N -|- lime | | 244.1 | 193.7 | 65.9 |

tion although no total N analysis was made to support this statement. The soils were acidic to slightly neutral in reaction. The addition of lime raised the pH of the soil and consequently stimulated bacterial processes such as ammonification, nitrification and denitrification. Of these three biological processes, ammonification is the least sensitive to pH.

The use of $CaCO_3$ at the rate of 2.5 tons per hectare raised the pH of the soils by 0.4 to 1.1 units. The changes in soil reaction during the process of nitrification are shown in table 4. In the unlimed soils, the pH dropped to as low as 4.4 in 28 days. The oxidation of ammonium sulfate brings about the formation of nitric acid in addition to sulfuric acid, and the acids produced cause the pH to fall progressively during nitrification. This is expected because the soils are of sandy texture. The clay contents ranged from 2.6 to 3.6 per cent and the buffering capacities are mainly due to organic matter.

From these observations one can predict the deleterious effects

TABLE 4.—*Changes in pH with time of incubation*

| SAMPLE NO. | TREATMENT | INCUBATION PERIOD IN DAYS | | | |
|---|---|---|---|---|---|
| | | 0 | 7 | 14 | 28 |
| CN-13 | Control | 5.0 | 5.2 | 5.7 | 5.9 |
| | 200 ppm N | 5.1 | 5.7 | 5.2 | 4.8 |
| | 200 ppm N -\|- lime | 6.0 | 7.2 | 7.2 | 6.6 |
| CS-13 | Control | 5.8 | 5.0 | 6.2 | 6.2 |
| | 200 ppm N | 5.4 | 5.3 | 5.1 | 4.6 |
| | 200 ppm N -\|- lime | 6 7 | 5.9 | 5.8 | 5.1 |
| CS-33 | Control | 5.7 | 5.9 | 5.9 | 6.0 |
| | | 5.6 | 5.3 | 5.3 | 5.0 |
| | 200 ppm N + lime | 6.0 | 5.8 | 5.8 | 5.6 |
| AL-13 | Control | 5.4 | 5.6 | 5.9 | 6.3 |
| | 200 ppm N | 5.4 | 5.8 | 5.5 | 5.5 |
| | 200 ppm N -\|- lime | 5.9 | 7.0 | 6.5 | 5.8 |
| AL-23 | Control | 5.6 | 6.0 | 6.3 | 6.5 |
| | 200 ppm N | 5.7 | 5.7 | 5.3 | 5.0 |
| | 200 ppm N -\|- lime | 6.8 | 6.5 | 6.2 | 5.5 |
| SOR-33 | Control | 5.3 | 5.5 | 5.5 | 5.7 |
| | 200 ppm N | 5.4 | 5.2 | 5.3 | 4.4 |
| | 200 ppm N -\|- lime | 6.1 | 6.2 | 5.2 | 5.0 |

of continuous use of ammonium sulfate or acid-forming fertilizers in sandy soils. Up to the present time ammonium sulfate is the most widely used commercial source of nitrogen in the Philippines. Galvez *et al.* (1955) observed significant drops in the pH of citrus orchard soils in Lipa as a result of continuous heavy applications of ammonium sulfate. Lime can counteract the effect of acids produced during nitrification. However, excessive use of lime can also be detrimental. Alkaline reaction and high levels of applied ammonium or ammonium-forming fertilizers can result in the accumulation of nitrite in the soil by means of an inhibition of *Nitrobacter* by free ammonia (Stojanovic and Alexander, 1958). Losses of applied nitrogen through volatilization may also occur in alkaline condition.

The data suggest that the soils used in this study support actively nitrifying organisms which are apparently adapted to low pH. The experiment is not comparable to the nitrification process that actually occurs in the field as soil samples incubated in petri

dishes in the laboratory are placed under controlled and artificial conditions. Despite the limitations of the method used, the study has shown that Bicol soils from cadang-cadang infected plantations have high nitrate supplying potential.

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